ARS/BLM COOPERATIVE STUDIES

REYNOLDS CREEK WATERSHED

Northwest Watershed Research Center
Western Region
Agricultural Research Service
U. S. Department of Agriculture

INTERIM REPORT NO. 12

Cooperative Agreement No. 12-14-5001-6028

For Period January 1, 1981 to December 31, 1981

TO

Denver Service Center
Bureau of Land Management
U.S. Department of Interior
Denver, Colorado

FEBRUARY 1982

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NOTE: Generally, a variety of watershed data are compiled on a calendar year basis. However, the water year, beginning October 1 and ending September 30, has proven best for hydrologic comparisons.

INTRODUCTION

Cooperative watershed research between the Agricultural Research Service, U. S. Department of Agriculture, and the Bureau of Land Management, U. S. Department of Interior, was initiated in 1968 under Cooperative Agreement No. 14-11-0001-4162(N). Also, the Memorandum of Understanding, dated July 6, 1960, which is part of the Cooperative Agreement, specifies the overall responsibility of each agency.

This interim report summarizes progress and results on the Reynolds Creek Watershed and supporting studies on the Boise Front from October 1 through September 30, 1981. Data collection, processing, analyses, and reporting are according to the FY 1981 work plan. Progress reports are given by the individual sections of the work plan. A copy of the FY 1981 work plan precedes the progress reports.

Supporting information and data are presented in Northwest Watershed Research Center Annual Reports for 1972 and prior years, and in Interim Reports No. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 for the ARS-BLM studies in the Reynolds Creek Watershed under Cooperative Agreement No. 12-14-5001-6028.

The research program at the Northwest Watershed Research Center, which includes field, laboratory, and computer-based studies, services action agency needs and contributes to the sciences of watershed hydrology and watershed management. Cooperative research with user agencies, such as BLM and SCS, and with State Universities in Idaho and Utah serves to enhance the application of research findings.

Research investigations at the Center include the following: (not in order of priority)

1. Snow Hydrology - Investigations on deposition and redistribution of snow, energy balance and melt processes of snowpacks, and water supply forecasting of snowmelt runoff. Research on improving water supply forecasting utilizes SCS SNOTEL and snow course data, and is conducted in cooperation with them and the National Weather Service. Snow research also contributes to the ARS AgRISTARS program. Snow research for mid-elevation rangeland watersheds is conducted on the Reynolds Creek Experimental Watershed. (A. L. Huber and K. R. Cooley, Hydrologists).

2. Water Quality - Investigations center on the effects of grazing systems on rangeland water quality. This research has identified rangeland non-point pollution sources and is evaluating the effects of management practices. Winter holding and feeding areas in the Reynolds Creek valley are being studied as a potential pollution source. The occurrence and movement of fecal coliform bacteria are being studied on the

Reynolds Creek Watershed and also on the Boise Front. Computer modeling of streamflow water quality is underway. Cooperative research is with BLM, the University of Idaho, and the Idaho Fish and Game Department. (G. R. Stephenson, Geologist).

3. Runoff and Water Yield - Investigations are developing and evaluating watershed runoff and water yield models. Winter season runoff events are major flood and sediment producing events on range and agricultural watersheds of the interior Northwest. Rainfall, occurring with melting snow on frozen soil, combines to generate these critical runoff conditions. Research on frozen soil hydrology is cooperative with the University of Idaho and other Pacific Northwest Area locations. (C. W. Johnson, Research Hydraulic Engineer, J. P. Smith, Hydrologist, C. L. Hanson, Agricultural Engineer, and K. R. Cooley, Hydrologist).

4. Erosion and Sediment Yield - The Universal Soil Loss Equation (USLE) requires modifications when applied to semiarid rangeland watersheds in the Northwest, especially for use with frozen soil and melting snow conditions. The USLE and sediment yield equations, such as the MUSLE, used by BLM and SCS on rangelands are being evaluated. Bedload studies are identifying the magnitude of bedload and suspended sediment transport in steep, rocky channels. Streams on the Reynolds Creek Experimental Watersheds are utilized in these erosion and sediment studies. (C. W. Johnson, Research Hydraulic Engineer).

5. Rangeland Vegetation - Investigations on the forecasting of rangeland forage production are underway. In cooperation with BLM, vegetation study sites established on the Reynolds Creek area are being used to evaluate the effects of livestock grazing. Also, rangeland forage forecasts were developed in cooperation with BLM in Montana. On the Reynolds Creek Watershed, three plant adaptability nurseries were established in cooperation with the Forest Service. A coordinated ARS project on rangeland resource modeling is underway. (J. R. Wight, Range Scientist, and C. L. Hanson, Agricultural Engineer).

6. Precipitation - Research is focused on developing and testing models for predicting the precipitation input to rangeland as influenced by elevation, aspect, and season. A study on "acid" precipitation is being initiated. (C. L. Hanson, Agricultural Engineer, and G. R. Stephenson, Geologist).

7. Soils - Research on modeling soil infiltration is being conducted in cooperation with SCS. Published soil water retention data have been used to predict Green-Ampt infiltration equation parameters. Procedures to predict the influence of management practices on infiltration and soil water storage are under development. (D. L. Brakensiek, Research Hydraulic Engineer, and W. J. Rawls, Hydrologist - Beltsville, Maryland).

8. Watershed Modeling - Combining all components of rangeland watershed hydrology and resources into a rangeland watershed model is underway. Development of a watershed model will provide the manager with a tool for making rangeland management decisions. Alternative watershed practices and conditions can be evaluated without lengthy and costly field installations. Component models under development and/or testing include watershed evapotranspiration, soil moisture storage, and infiltration and runoff. A major effort underway involves the coordination of major ARS activities in Rangeland Hydrology and Resource Modeling. (C. L. Hanson, Agricultural Engineer, J. R. Wight, Range Scientist, and Staff).

Introduction Figure 1 locates major experimental sites on Reynolds Creek Watershed.

Additional copies of this report or further information on reported work can be obtained from:

Northwest Watershed Research Center
USDA, Agricultural Research Service
1175 South Orchard, Suite 116
Boise, Idaho 83705

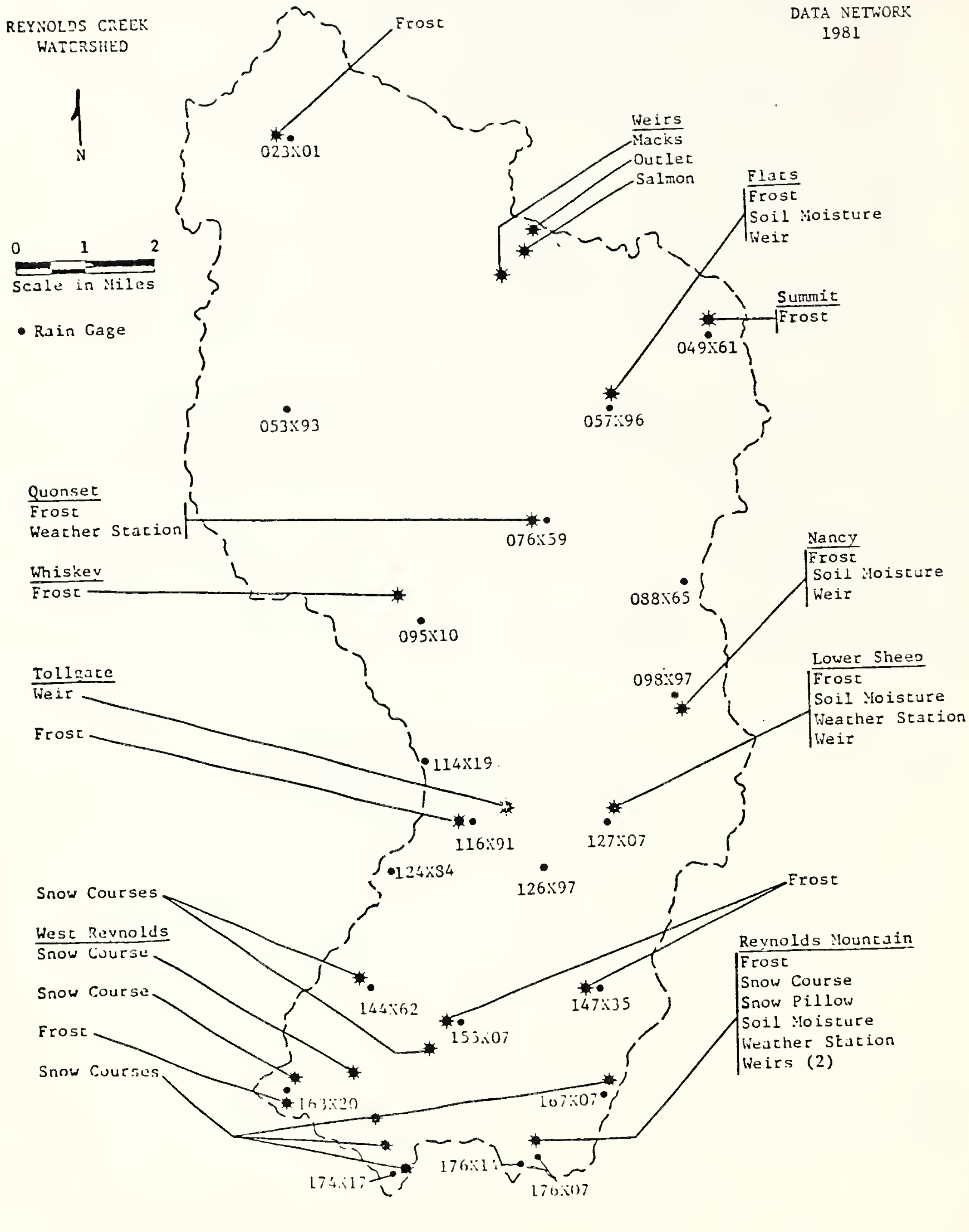

Figure 1.--Reynolds Creek Watershed.

STAFF

NAME	TITLE	SERVICE DATES*
Aaron, Virginia M.	Hydrologic Technician	
Barrett, Mike	Boise State University Cooperator-Technician	11/1/81-present
Belknap, Stephen P.	University of Idaho Cooperator-Employee	
Brakensiek, Donald L.	Research Hydraulic Engineer (LL & RL)	
Burgess, Michael D.	Electronic Technician	
Butler, Donna M.	Administrative Officer	
Charles, Kathleen	Boise State University Cooperator-Technician	10/26/81-12/7/81
Cooley, Keith R.	Hydrologist	
Coon, Delbert L.	Hydrologic Technician	
Engleman, Roger L.	Mathematician	
Evans, Randy	University of Idaho Cooperator-Technician	11/1/81-present
Gordon, Kathy	Boise State University Cooperator-Technician	3/16/81-present
Griffith, Suzann C.	Clerk Typist (Perm., 32 Hr/Wk)	11/2/80-6/1/81
Hanson, Clayton L.	Agricultural Engineer	
Harris, James H.	University of Idaho Cooperator-Scientific Aide III	terminated 7/18/81
Hennefer, Shari L.	Secretary	
Hoagland, Roy M.	Engineering Equipment Operator	
Huber, A. Leon	Hydrologist	
Johnson, Clifton W.	Research Hydraulic Engineer	
Miller, Cindy	Boise State University Cooperator-Technician	
Morris, Ronald P.	Hydrologic Technician	
Mosby, John D.	Boise State University Cooperator-Technician	11/17/80-2/23/81
Nelson, William	Boise State University Cooperator-Technician	9/2/81-12/13/81
Robertson, David C.	Hydrologic Technician	
Royston, Janice L.	Boise State University Cooperator-Technician	
Sherman, David D.	Boise State University Cooperator-Technician	11/10/80-10/30/81
Smith, Jeffrey P.	Hydrologist	
Springer, Everett	Utah State University Cooperator-Modeler	9/1/81-present
Stephenson, Gordon R.	Geologist	
Veigel, Anne P.	University of Idaho Cooperator-Scientific Aide II	
Wight, J. Ross	Range Scientist	
Wilson, Glenna A.	Purchasing Agent	

*If other than whole year.

BLM-ARS ANNUAL WORK PLAN FOR FY 1981

INTRODUCTION: The following work plan items contribute to the objectives of Paragraph III of the Bureau of Land Management Interagency Agreement No. YA-515-IA8-21 dated September 19, 1978. Certain items in the work plan represent a continuation and/or completion of work from previous years. In some cases, the continuation represents collection of hydrologic data or watershed resource inventories. This is required for sampling the influence of climatic variability on hydrologic factors and cumulative effects of rangeland management practices. USDA-ARS watershed management research not a part of this work plan will, in many instances, supplement and/or complement the following work plan items:

1. PRECIPITATION

Continue operation of the precipitation network on Reynolds Creek. A new site (098X97) was established at the Nancy runoff plot on October 1, 1980 and the old Summit site (049X61) was reactivated on the same date. The four sites on the Boise Front will be discontinued on January 1, 1981. Monthly and annual precipitation models will be applied to comparable rangeland areas in Idaho, Oregon, and Nevada. Stochastic modeling of precipitation events on Reynolds Creek will continue.

2. VEGETATION

Complete testing of Saxton soil water model. Initiate an analysis of Reynolds Creek data on species composition and cover at nine grazed and four ungrazed sites to determine sampling variability with application to the design of vegetation monitoring systems. Bitterbrush utilization surveys will continue on the Boise Front, depending on technical support from Idaho Fish and Game. Finalize the preparation of a Reynolds Creek Watershed soil/vegetation data base.

3. RUNOFF

Continue runoff data collection at two main stem, two tributary and three source watersheds on Reynolds Creek. Runoff sites on the Boise Front study areas will be terminated January 1, 1981. Runoff records from the Saval Ranch (Nevada) project will be processed as funding and records are available. Runoff model testing will commence with Reynolds Creek Watershed data. Green and Ampt infiltration parameters will be utilized in modifying runoff prediction equations, such as the SCS runoff equation.

4. EROSION AND SEDIMENT

Continue data collection at four Reynolds Creek sites and terminate the two sites on the Boise Front on January 1, 1981. An evaluation of the relationship between plant biomass and vegetative cover on ungrazed sites will be conducted to improve the cover factor in USLE. Continue the evaluation of USLE, MUSLE, and PSIAC factors for rangeland watersheds.

5. WATER QUALITY

Continue the evaluation of water quality models with Reynolds Creek data. Determine the influence of streamflow channel characteristics, such as sediment, temperature, and flow velocity on quality indicators, such as fecal coliform. Continue water quality observations on the Boise Front rest-rotation system and compare the effects of cattle and deer grazing. Investigate the survival of E. coli in stream water, in stream sediments, and in off-stream sites.

SUMMARY OF WORK PLAN RESEARCH FINDINGS

BY WORK PLAN SECTIONS

1. PRECIPITATION

Personnel Involved

C. L. Hanson, Agricultural Engineer	Supervises the planning and design of precipitation studies; performs analyses and summarizes results.
K. R. Cooley, Hydrologist	Coordinates ARS hydrologic research at the Saval Ranch, Nevada Research Project.
V. M. Aaron, Hydrologic Technician	Responsible for data reduction and processing.
D. L. Coon, R. P. Morris, and D. C. Robertson, Hydrologic Technicians	Responsible for data collection, compilation, and assist with analyses.
R. L. Engleman, Mathematician	Responsible for data compilation and assists in analyses.
R. Evans, Cooperator (U of I)	Responsible for data reduction and processing.
J. Royston, Cooperator (BSU)	Assists in hydrologic data reduction.

Reynolds Creek precipitation: The precipitation network in operation on the Reynolds Creek Watershed is shown in Introduction, Figure 1.

The four precipitation sites listed in Table 1.1 represent the precipitation conditions that existed on the watershed in water year 1981. Precipitation ranged from 2.3 inches below average at the low elevation site 076X59 (3965 feet) to 14.5 inches below average at the high elevation site 176X07 (6760 feet). The much below average annual precipitation amounts were due to the very dry conditions during the fall and early winter. Precipitation during the spring and early summer (March-June) was at or above average, which resulted in good vegetative growth. The annual total at the Boise airport was 0.7 inch above average because of above average precipitation during March and April and near normal precipitation most other months.

Boise Front precipitation - 1981

Precipitation gages were removed from the Boise Front the week following January 1, 1981.

Wyoming shield gage study: Preliminary data analysis indicates that rain and wet snow catch by the Wyoming shield gages is equivalent to the catch by the dual-gage system when 1.8 is used as the coefficient in the dual-gage amount equation. We are continuing this study because our analysis of snowfall measurement has not been completed.

Heated precipitation gages: A study was initiated during the fall of 1980 to determine if the snow catch by heated precipitation gages is comparable with that measured by standard weighing and recording gages. Preliminary analysis indicates that the heated gages catch about 30 percent less. This study is continuing during the 1981-82 winter because of the small number of snow events during 1980-81.

Saval Ranch: ARS involvement in the hydrologic aspects of the BLM-ARS Saval Ranch Project continued this year. Major emphasis centered on insuring that quality hydrologic data would be available when model development and testing is initiated. To meet this objective, efforts were made to improve and standardize precipitation collection equipment, a data processing technician was hired and is being trained, and a computerized data file was initiated.

During the week of June 22-26, 1981, Keith Cooley and Dave Robertson visited the Saval Ranch for the purpose of installing better gage mounting brackets at all of the precipitation sites, and to tighten and adjust the Wyoming Shields as needed. The original wooden mounting brackets had become loose due to drying and splitting caused by weathering processes and vibration. The new steel brackets consisted of 1/4" thick steel plates bolted directly to the bottom of the gage (eliminating the 3-legged stand provided by the

Table 1.1.--Water year precipitation (inches) at four locations on Reynolds Creek Watershed and the Boise Airport.[1/]

Site	Elevation (ft)	Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
076X59	3965	1981	.350	.884	1.528	.283	.888	1.090	1.722	1.021	.930	.020	.070	.090	8.876
		1963-1981	.842	1.176	1.203	1.493	.787	.917	.991	.885	1.338	.273	.746	.569	11.190
116X91	4760	1981	.707	1.074	2.370	.640	1.943	1.574	2.617	1.599	1.445	.130	.110	.190	14.399
		1963-1981	1.434	2.054	2.341	2.666	1.545	1.682	1.775	1.260	1.601	.389	.703	.796	18.246
155X07	5410	1981	.929	1.586	3.864	1.307	2.794	3.432	2.851	2.228	1.226	.290	.120	.287	20.914
		1963-1981	1.985	3.415	3.746	4.552	2.700	2.784	2.357	1.771	1.836	.608	1.034	1.029	27.817
176X07	6760	1981	1.083	2.277	4.061	2.830	2.820	5.124	3.039	2.767	1.457	.310	.150	.458	26.376
		1963-81	2.219	5.365	5.843	7.880	4.396	4.264	3.514	2.429	2.180	.577	1.102	1.117	40.886
Boise Airport	2838	1981	.300	1.260	1.490	1.200	1.020	2.760	1.930	.950	.770	.230	.130	.360	12.400
		1941-1981	.829	1.316	1.351	1.480	1.143	1.118	1.167	1.233	1.000	.206	.339	.513	11.695

1/ Raingage locations are shown on Introduction, Figure 1.

manufacturer), three 1/2" diameter leveling bolts, and three angle braces anchored to the posts with lag bolts. Overall, the new brackets appear to have increased mounting sturdiness, and should reduce gage vibration caused by the wind.

The gage orifices were also repositioned to be in the same plane as the top of the inner shield of the double shielded Wyoming Shield configuration. Some were found to be up to 6 inches low, or high, probably due in part to settling of the shields since installation. Although gage catch may not have been affected significantly by the discrepancy in height, it seemed best for future comparisons to have them all positioned the same.

The calibration of all gages was checked, and all appeared to be working satisfactorily, although some were off slightly at the higher depth readings.

In October, Randy Evans was hired to process the Saval data. He has been trained to mark the precipitation charts, and has marked all of the charts from June, 1979 to September, 1981. He is now in the process of being trained to digitize the chart data, and enter it into the computerized data file that is being developed.

Neil Hutten, stationed at Elko, Nevada, also received training in precipitation gage calibration and field procedures during a two-day visit to Boise in late August.

The computerized data file that is being developed will contain all of the hydrologic data being collected at Saval Ranch. This will include breakpoint continuous precipitation and runoff from the small watersheds; and daily values of evaporation, maximum and minimum temperature, solar radiation, humidity, and runoff from the four USGS gaging stations as processed and made available by USGS. The precipitation, small watershed runoff, and evaporation charts will be processed at Boise. Daily solar radiation, maximum and minimum temperature, and humidity will be recorded on data sheets by Neil Hutten and sent to Boise, so these data can be entered into the file. Ouput from the data file can then be obtained in several formats, including reproductions of the file on magnetic tape, and analyzed information such as storm EI, seasonal or annual EI, intensity characteristics, etc.

Examples of breakpoint precipitation data for three storms were presented in Interim Report No. 11. An example of daily and monthly precipitation data is presented in Table 1.2 for the last half of 1979 for station #4. Table 1.2 represents a standard type of output that will be available, but almost any format could be provided.

During the week of November, 9-13, Keith Cooley participated in a modeling workshop at Elko to help develop an initial version of an integrated model for the Saval Project. Many of the hydrologic components were based on previous ARS research, and were described by Cooley for inclusion in this model.

At both the June and November visits to Elko, Keith Cooley participated in sessions held to discuss future direction of the hydrologic aspects of the Saval Project. Recommendations were made, based on previous watershed hydrology experience at Boise, to support and facilitate the collection of the proper hydrologic data that will be required to meet future project objectives.

Table 1.2.--Daily and monthly summary of precipitation for July through December, 1979; station #4, Saval Ranch project, Elko, Nevada.

DAY	MONTH					
	JUL	AUG	SEP	OCT	NOV	DEC
1	---	---	---	---	---	---
2	---	---	---	---	---	0.020
3	---	---	---	---	0.290	---
4	---	---	---	---	0.120	---
5	---	---	---	---	---	---
6	---	---	---	---	---	---
7	---	---	---	---	---	---
8	---	---	---	---	---	---
9	---	---	---	---	---	---
10	---	---	---	---	---	---
11	---	---	---	---	---	---
12	---	0.039	---	---	---	---
13	---	0.091	---	---	---	---
14	---	0.220	---	---	---	---
15	---	---	---	0.140	---	---
16	---	0.010	---	---	---	---
17	---	0.130	---	---	0.100	---
18	---	0.160	---	0.151	0.120	---
19	---	0.090	---	1.697	0.010	---
20	---	0.020	---	0.282	---	---
21	0.300	0.010	---	0.130	---	0.140
22	0.700	---	---	---	0.226	0.040
23	0.010	---	---	---	0.154	0.100
24	---	---	---	---	0.330	---
25	---	---	0.390	---	0.590	0.100
26	---	---	---	---	0.050	---
27	---	---	---	---	---	---
28	---	---	---	0.080	---	---
29	---	---	---	0.070	---	---
30	---	0.150	---	0.055	---	---
31	---	---	---	0.135	---	---
TOTAL	1.010	0.920	0.390	2.740	1.990	0.400

ANNUAL AND MONTHLY PRECIPITATION GENERATION FOR IDAHO AND SURROUNDING STATES

Data from 33 stations in Idaho and 25 stations in states surrounding Idaho are being used to develop procedures for generating annual and monthly precipitation amounts. Most station data sets being used are 40 year (1940-79) records; however, a few records are shorter because of missing data.

The procedure that was developed to generate annual series is based on the lognormal distribution and is a shortened version of the procedure discussed in Interim Report No. 11. Mean annual precipitation is the only variable required in this procedure because only mean annual precipitation and the associated coefficient of variation are used in the generation.

The equation for generating annual precipitation using the lognormal distribution is:

$$Y = \exp(u_{\ell nx} + \sigma_{\ell nx} y) \qquad [1]$$

where,

Y = generated annual precipitation values

$u_{\ell nx}$ = the mean of the $\log_e$ values

$\sigma_{\ell nx}$ = the standard deviation of the $\log_e$ values of the site where data are available

y = a pseudo-random normal deviate [N(0,1)].

The equations for obtaining $u_{\ell nx}$ and $\sigma_{\ell nx}$ from the mean annual are (Haan, 1977):

$$u_{\ell nx} = \tfrac{1}{2}\ell n[\overline{X}^2/(C_v^2 + 1)] \qquad [2]$$

$$\sigma_{\ell nx} = [\ell n(C_v^2 + 1)]^{\frac{1}{2}} \qquad [3]$$

and,

$$C_v = 0.262 - 0.00014\overline{X} \qquad [4]$$

$(R^2 = 0.613)$

where,

$\overline{X}$ = average annual precipitation (mm) obtained from records or maps

C_v = coefficient of variation.

The generating procedure is as follows:

1. Compute the mean annual precipitation ($\overline{X}$) for the location in question from climatic records, maps, etc.

2. Compute the coefficient of variation by using Equation [4].

3. Compute $u_{\ell nx}$ and $\sigma_{\ell nx}$ by using Equations [2] and [3].

4. Obtain as many values of y as is required from a table of pseudo-random normal deviates [N(0,1)] or from computer programs for generating these values.

5. Compute the annual precipitation series by using Equation [1].

Discussion: The coefficient of variation (C_v) values were plotted on maps, to determine if it varied by location in the study area. No regional trends could be found from the maps, so all of the data were analyzed in one group. There is considerable scatter among the data points, but the Coefficient of Determination ($R^2 = 0.613$) indicates that there is a reasonable relationship between average annual amount and the Coefficient of Variation.

The summary of 50-year simulations listed in Table 1.3 are for locations where the average annual precipitation was calculated to be approximately 250 and 750 mm. The simulated standard deviation was greater than measured by about 12 percent. The simulated range of annual totals was about 12 percent greater than the measured values.

MONTHLY PRECIPITATION GENERATION

The monthly generation procedures currently being developed for Idaho and surrounding states are based on the monthly precipitation scheme developed for the Reynolds Creek Watershed data set, as reported in Interim Report No. 11. Preliminary analysis indicates that the generating procedures outlined in Interim Report No. 11 can be used to generate monthly precipitation amounts for Idaho and surrounding states.

REFERENCES

Haan, C.T. 1977. Statistical methods in hydrology. The Iowa State University Press, Ames, Iowa. 378 pp.

Table 1.3.--A summary of 50-year simulations where the calculated average annual precipitation used in equations [1] through [4] was approximately 250 and 750 mm.

	Average Precipitation (mm)	Coefficient of Variation	Standard Deviation (mm)	Range of Annual Totals (mm)
Simulated	251	.24	61	157 - 425
Deer Flat Dam, ID	251	.21	53	126 - 355
Malheur, OR	247	.22	55	131 - 353
Simulated	747	.18	137	476 - 1162
Saint Maries, ID	762	.17	126	465 - 1021
Kellogg, ID	773	.16	125	485 - 1037

2. VEGETATION

Personnel Involved

J. R. Wight, Range Scientist	Plans, designs, and supervises field studies and coordinates research activities and prepares reports.
C. L. Hanson, Agricultural Engineer	Performs computer analyses relative to field studies and assists in planning field studies.
K. R. Cooley, Hydrologist	Plans, designs, and supervises soil water modeling.
J. P. Smith, Hydrologist	Assists in vegetation data reduction.
D. C. Robertson, Hydrologic Technician	Supervises hydrologic data reduction and performs computer operations.
D. L. Coon, Hydrologic Technician	Assists in data collection and noting field observations, including soil moisture measurement and calibration.
M. Barrett, Cooperator (BSU)	Assists in hydrologic data reduction.
C. Miller, Cooperator (BSU)	Assists in hydrologic data reduction.
D. Sherman Cooperator (BSU)	Assists in hydrologic data reduction.

Reynolds Creek (Reynolds Creek site locations are shown in Introduction, Figure 1).

Soil water balance models: Progress made in testing Wight's and Saxton's soil water balance models consisted of: (1) completion of a test data file containing six or more years of data for each of four Reynolds Creek watersheds; (2) transforming the format of Saxton's model to make it compatible with the Center's computer, and checking it against a test data set; (3) obtaining the necessary input factors and boundary condition parameters to make a calibration run with Saxton's model using the 1979 data from the Flats site; (4) running Wight's model continuously for six years (1975-1980) using the calibration year; and (5) making a comparison of soil moisture output from the models with measured soil moisture at the Flats site for 1979.

The computerized hydrologic data file for testing the soil water balance models has been completed. The file consists of daily values of precipitation, runoff, solar radiation, and maximum and minimum temperature for six or more years at four Reynolds Creek sites. Daily values of solar radiation for the Boise airport for the same years have been obtained and entered into the file for correlation and use in estimating missing data. Daily pan evaporation data for the summer periods at the two upper watersheds (Reynolds Mountain and Lower Sheep Creek), and at a third site, representing the two lower watersheds (Nancy and Flats), is also included. Soil moisture data for five layers, down to about 136 cm, are used as a check on the models. The four watersheds vary in elevation from 1180 m to 2160 m, and in size from 0.8 ha to 40 ha. The annual precipitation ranges from 24 cm at the lower sites to 102 cm at the upper site. Vegetation consists mainly of grasses, sagebrush, and shadscale at the Flats, and grasses and sagebrush at the other sites. However, they do represent an increasing amount of larger shrub and woods with increasing elevation. Soils vary from fine loam to gravelly loam. These four sites were chosen for testing the models because of data availability and the range site characteristics represented.

Although the copy of Keith Saxton's model provided to us was written in FORTRAN, it had to be modified to run on the Center's computer. THe program was modified, and was subsequently run using a check data set provided by Saxton.

In addition to hydrologic factors which drive the model, such as daily precipitation, runoff or curve number, and pan evaporation, Saxton's model requires a knowledge of several crop or vegetation parameters or relationships, and soil characteristics. These include: the root distribution within the soil profile; the canopy cover with time during the year, and the susceptibility of this cover to moisture stress; a vegetation phenology curve for the year, and the susceptibility of this curve to moisture stress; a curve to represent the relationship between moisture availability and crop stress; the type, number of soil layers, and their thickness; and the dates when the range vegetation begins to grow and ceases to grow.

Some of the parameters, such as soil characteristics, may not be available, but can be fairly easily obtained by taking soil samples. However, vegetation relationships are not readily available in most range situations. Therefore, much estimating is required, because the relationships presented by Saxton for agricultural crops in the Mid-west may not apply to rangeland vegetation on the Reynolds Creek Watershed. A sensitivity analysis, showing the effect of variations in these relationships on predicted soil water, has not been performed to date, but will be important in determining what level of accuracy is required.

After calibration of Wight's model using the 1979 Flats site data (see Interim Report No. 11), a continuous run for the years 1975 through 1980 was performed. The measured soil moisture at the beginning of 1975 was used as a starting point, and then the predicted soil moisture at the end of each year was used as the beginning point for the next year. Results for each year are presented in Table 2.1. Shown are the predicted and observed soil moisture by layer, and the total water in the soil profile at the end of each year. The total water, as predicted by the model, differs from the observed amounts by up to nearly 30 percent. The greatest differences are associated with the wetter years, while predicted totals are almost identical to measured totals for the drier years of 1979 and 1980. These results may indicate that the model as used removes too much water, thus reaching the lower limits for this soil nearly every year. Observation of predicted soil water in individual soil layers strengthens this suggestion. As shown in Table 2.1, the lower three layers reach essentially the same value at the end of each year, indicating that this value (which is different for each layer) is the lower limit of available water.

Wight's model functions as a series of cascading reservoirs; that is, all of the water infiltrated is assumed to be stored in the first layer until it reaches its field capacity, at which time any additional infiltration is assumed to be stored in the second layer, and so on. Since most of the roots are in the upper layers, and evaporation from the bare soil surface only involves the first layer, the majority of activity or water transfer takes place in the upper layers. Therefore, except in relatively wet years, the model would not show any water reaching the lower layers. This appears to be the situation shown in Table 2.1, where the first four years are relatively wet and measured water in the lower layers exceeds predicted. Whereas, for the last two drier years, the measured water and predicted water are essentially the same in the lower layers.

An adequate comparision of the two models should include a comparison of factors needed to run the models in addition to final results. As noted previously (see Interim Report No. 11), these two models represent different levels of complexity. Saxton's model is more complex and attempts to include a representation of all physical processes involved, while Wight's model is a more simplified approach, which considers only broader or more general relationships. The data and model parameters needed also vary as shown in Table 2.2.

Table 2.1.--Comparison of Measured and Predicted soil water by layers using Wight's Model for 1975-1980 and Saxton's Model for 1979, in centimeters.

LAYER	1975		1976		1977		1978		1979			1980	
	WIGHT PREDICTED	MEASURED	WIGHT PREDICTED	MEASURED	WIGHT PREDICTED	MEASURED	WIGHT PREDICTED	MEASURED	WIGHT PREDICTED	MEASURED	SAXTON PREDICTED	WIGHT PREDICTED	MEASURED
0 - 23cm	6.21	4.32	1.91	2.90	6.16	5.59	4.19	4.04	3.53	2.51	2.64	5.67	4.06
23 - 46cm	3.28	3.56	2.08	2.97	3.17	5.00	2.13	3.58	2.08	2.24	2.29	2.17	3.18
46 - 76cm	2.68	4.32	2.65	3.99	2.62	4.11	2.74	4.34	2.62	2.62	3.07	2.62	3.33
76 - 106cm	2.39	3.56	2.39	3.66	2.39	3.45	2.49	3.53	2.39	3.05	3.07	2.39	2.62
106 - 136cm	3.38	4.83	3.38	4.17	3.38	4.42	3.41	4.60	3.38	3.63	3.07	3.38	3.40
TOTAL	17.94	20.59	12.41	17.69	17.72	22.57	14.96	20.09	14.00	14.05	14.14	16.23	16.59
DIFFERENCE	2.65cm		5.28cm		4.85cm		5.13cm		0.05cm - 0.09cm			0.36cm	
% DIFFERENCE	13.3		29.8		21.5		25.5		0.4	--	0.6	2.2	

Table 2.2.--Input requirements for running Saxton's and Wight's soil water balance models.

SAXTON'S MODEL	WIGHT'S MODEL
Initial soil moisture	Initial soil moisture
Daily precipitation	Daily precipitation
Daily runoff or curve number	--
Daily pan evaporation	Daily max & min temperature
Monthly pan coefficient	Daily solar radiation
Annual pan evaporation	--
Soil type by layer	Soil moisture characteristics by layer
Layer thickness	Layer thickness
Δ time interval	--
Δ soil pressure tolerance	--
Root distribution	Soil temperature curves by layer
Canopy cover curve	Canopy cover factor
Canopy susceptibility	--
Phenology curve	Plant growth curve
Phenology susceptibility	--
Moisture-stress curves	--
Planting & harvest dates	Starting growth date

Although most of the parameters needed can be obtained from the literature or data sets, with some modifications made for different site conditions, several of the parameters require information that is not readily available for rangeland sites. This is especially true for Saxton's model where six parameters or relationships concerning vegetation roots, growth, and stress are needed. In order to run the model, some information from the literature was used for root distribution, realizing that such data was collected from sites with different climatic and soil characteristics. Canopy and phenology curves were developed from vegetation measurements made at Reynolds Creek, also knowing that these data do not represent potential unstressed conditions. The canopy and phenology susceptibility curves, and the moisture stress curves were used as presented by Saxton, even though these were developed from studies based on irrigated crops in the Mid-west.

In using Wight's model, three factors require data that are not readily available. Of these, the plant growth curve, which is similar to the phenology curve in Saxton's model, is the most difficult to make site specific, for the same reasons previously discussed. Data to develop soil temperature curves by layer are also

lacking; however, some models based on air temperature are available, and since the temperature of the deeper layers varies only slightly through the year, these curves can be estimated with some confidence. The third factor not readily available is the canopy cover factor, which is merely a ratio of transpiring canopy to total canopy cover. Changes in this ratio of up to 50 percent made only minor changes in total soil water at years end; therefore, at least in this case, great accuracy was apparently not required in this factor.

A comparison of the predicted and measured soil moisture, by layers, is presented in Figure 2.1 for both models. The ability of the models to predict variations in soil water status is of considerably more interest than the number of input items required, as long as these items can be obtained in reasonable time, and with reasonable accuracy. As noted in Figure 2.1, most of the changes in predicted and measured soil mositure occur in the top 46 cm, or top two layers. In general, it appears that Wight's model follows the measured points somewhat better than Saxton's, except for the middle layer. The total amounts of moisture in the profile predicted by the two models are essentialy the same at the end of 1979, and bracket the measured value. Based on these results, it would be easy to conclude that since both models produced essentially the same results, but Wight's model is easier to use, then why bother with the extra effort, time, and computer space required to use Saxton's model? However, these results are for only one year at a single location, and considerable effort was expended to make the predictions match the measured water content, since this was the calibration year. As noted in Table 2.1, Wight's model produced results that differed by nearly 30 percent from measured values for other years. Therefore, the tests will be continued on this and other sites to provide a more realistic comparison before conclusions are presented.

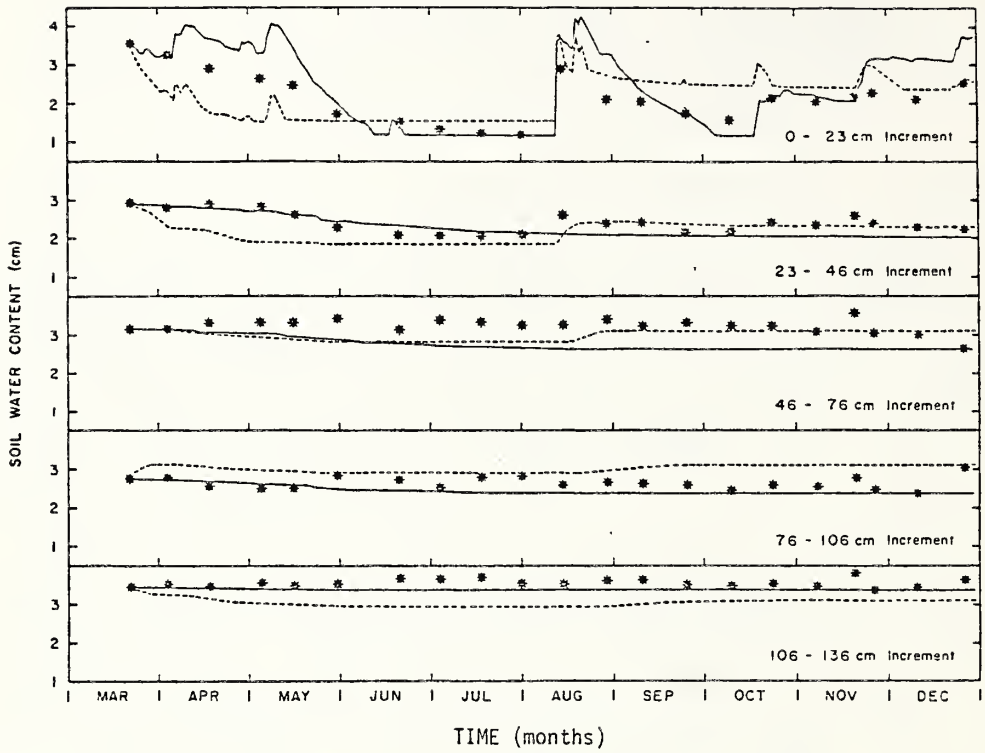

Figure 2.1.--Soil water content by layers predicted using Wight's model (solid line) and Saxton's model (dashed line) for 1979 at the Flats site, compared to measured values (represented by asterisks).

It should also be noted that both models are still being modified, and the versions used in these tests are not the latest versions, but rather the ones in existence when the study began. In most cases, especially for Saxton's model, changes have been minor, and would probably not alter results significantly. The two major changes in Wight's model are the addition of a curve number based runoff routine, and the addition of built-in plant growth curves of various shapes that can be selected by the user to represent vegetation growth at a particular site. Since significant runoff events are rare at the Flats site, the runoff routine would not be likely to alter results. The effects of using the built-in growth curves rather than the curve estimated from vegetation surveys, are not known at this time.

Boise Front: A decision was made in April, 1981, between BLM and ARS, Northwest Watershed Research Center, to discontinue the vegetation surveys on the Boise Front rest-rotation system. This decision was made because an additional two years of data would not be enough to show the effects of the rest-rotation system, and State Fish and Game funding cuts precluded a project management level suited for research purposes. It was agreed that the following research would substitute for the Boise Front study:

> Use Reynolds Creek vegetation and related resource data to evaluate rangeland monitoring techniques, key trend indicators, and sampling variability.

Overstory cover sampling methods: Overstory cover was measured by the wheel-point (Tidmarsh and Havenga, 1915; and von Broembsen, 1965), step-point (Evans and Love, 1957; and U.S. Department of Interior, 1979), and vertical point-frame (Goodall, 1952; National Academy of Sciences, 1962; and Hutchings and Pase, 1963) methods. Canopy cover was obtained from ten 100-point transects that were located in grazed areas at Flats (site 1), Nancy (site 2), and Whiskey Hill (site 3) study sites (see Figure 1). The wheel points were 2 feet from point to point. A pin guided by a notch in the boot was used in the step-point method. Plant hits with the wheel-point and step-point methods were recorded when any part of the pin hit a plant part. The point-frame was a 10-point frame with the pins 2.5 inches apart and sharpened to a fine point on the tip. Only hits on the point of the pin were recorded for the point-frame method. For the three methods, hits were recorded from the ground up with a possibility of four hits per pin. For example, the first recorded hit (ground level) would be litter, rock, basal plant cover, or bare ground. Only rock .08 inches or more in diameter was counted. Moving up the pin, subsequent hits were recorded. Only the first three above-ground hits were recorded, and if the same species was hit more than once per pin, only the first above-ground hit was recorded. In practice, the wheel-point and step-point pins were in place before the hits were observed; for the point-frame, the hits were observed as the pin was moved through the frame to ground level, but recorded from the ground up.

Results from this study are presented in Tables 2.3 and 2.4. The results show that the wheel-point and step-point methods give essentially the same results for both cover and frequency of occurrence. These results indicate that the wheel-point information obtained at the vegetation study sites on Reynolds Creek are directly related to survey data obtained by the step-point method used by BLM survey crews. The point-frame method measured less cover and a lower frequency of occurrence of the grasses. These results would be expected because only tip hits were recorded by the point-frame method and hits on the side of the pins were recorded for the other two methods. The pins were about 0.31 inches in diameter and represented a significantly larger area than did the pin tips.

Table 2.3.--Frequency of occurrence[1/] by the wheel-point, step-point, and point-frame methods.

	SITE								
	1			2			3		
	Wheel-Point	Step-Point	Point-Frame	Wheel-Point	Step-Point	Point-Frame	Wheel-Point	Step-Point	Point-Frame
Grasses	73	72	40	44	42	15	78	84	40
Cheatgrass brome	65	66	35	T[2/]	1	0	63	70	33
Sandberg bluegrass	T	T	T	40	38	14	8	7	3
Bottlebrush squirreltail	6	5	3	2	3	1	2	2	1
Forbs	15	14	7	25	21	19	25	26	16
Shrubs	14	14	8	18	16	17	41	35	27
Big sagebrush	7	7	4	18	15	16	27	23	18
Shadscale	6	6	3	--	--	--	--	--	--

1/ Frequency is the total number of hits divided by 1000 where no more than one hit per species was recorded for each point.

2/ Trace.

Table 2.4.-Cover in percent[1/] (includes foliar cover, mulch, rock, and bare ground) by the wheel-point, step-point, and point-frame methods.

	SITE								
	1			2			3		
	Wheel-Point	Step-Point	Point-Frame	Wheel-Point	Step-Point	Point-Frame	Wheel-Point	Step-Point	Point-Frame
Grasses	60	60	37	35	35	13	46	53	31
Cheatgrass brome	56	57	33	T	T	0	35	44	26
Sandberg bluegrass	T[2/]	T	T	33	33	12	6	6	2
Bottlebrush squirreltail	3	2	3	1	1	1	1	1	1
Forbs	7	7	5	10	8	13	8	7	9
Shrubs	11	10	7	16	13	16	36	29	25
Big sagebrush	6	6	4	15	13	16	25	21	18
Shadscale	4	3	3	NA	NA	NA	NA	NA	NA
Litter	3	2	16	6	5	13	4	4	25
Rock	1	2	5	2	4	8	1	1	1
Bare ground	18	19	30	31	35	37	5	6	9

1/ Cover is based on the first hit observed (going from the outer canopy to the ground surface) at each point, and is a percent of 1000 points for each method at each site.

2/ Trace.

Overall, the point-frame method measured grass cover as being 44 percent less than the other methods.

The hits of forb species were so few that the results were mixed, as was also the case for the shrubs at sites 1 and 2. At site 3 where the shrubs made up about 32 percent of the cover hits, the point-frame method measured less than the other two methods by 23 percent. As would be expected, the point-frame method measured more bare ground than the other methods. Because of the very small area of the pointed pin tip, it is less likely to encounter litter, rock, or basal plant cover. The higher cover of litter and rock measures by the point-frame method is somewhat unexpected, but may be due to the fact that as the wheel-point and step-point pins were pushed into the ground, the litter and rock were pushed aside and weren't touching the pin when the observations were made.

Point data obtained from the Flats and Nettleton sites were used to indicate how many step-points are required to measure basal cover within 10 and 20 percent of the population mean at the 80 and 90 percent confidence levels. As expected, the data in Table 2.5 shows that the number of step-points varies according to the variable being sampled. If the variable sampled covers a high percent of the surface, fewer samples are required than when the variable covers only a small percent of the area, i.e.--the shrubs and forbs at the Flats site.

Figure 2.2 shows the number of points required to measure cover at a given level of accuracy. As an example, if one wants to sample litter within 10 percent of the population mean at the 80 percent level of confidence, and litter covers 30 percent of the surface, line N2 shows that 400 points are required.

The information in Table 2.6 was developed from basal cover data obtained from the Nettleton grazed and ungrazed sites in 1975. These data show that significant differences in cheatgrass basal cover could have been measured with relatively few points, because of the large difference in basal cover between the two areas. The data also shows that several thousand points would have been required to establish that the difference measured in the basal cover of shrubs was statistically significant. In general, about 200 points in each area would be needed to detect cover differences of 5 percent or greater.

Vegetation yield measurements: One of the procedures used by the BLM to measure vegetation yield is the weight-estimate method. This procedure was also used to measure the vegetation yield on the Reynolds Creek Watershed study areas. Data for two years from two sites on Reynolds Creek Watershed were used to determine how many weight-estimates are required to estimate the mean yield, within a specific level of confidence (Table 2.7).

The information in Table 2.7 indicates that 20 samples are required to measure all but three of the yield groups shown in the table to

Table 2.5.--Example of number of points required to measure basal cover, based on 1975 data from the Flats and Nettleton sites.

COVER CLASS	FLATS					NETTLETON				
	MEASURED[1/] COVER	N1[2/]	N2	N3	N4	MEASURED COVER	N1	N2	N3	N4
Grasses										
Cheatgrass	.141	1657	997	415	250	.239	867	522	217	130
Total	.154	1497	900	374	225	.396	415	250	104	62
Forbs	.026	9851	5926	2554	1536	.026	9851	5926	2554	1536
Shrubs	.014	18800	11305	4699	2826	.030	8804	5296	2201	1324
Total Live Cover	.194	1132	681	283	170	.451	331	199	83	50
Litter	.040	6535	3931	1634	983	.396	415	250	104	62
Rock	.129	1843	1109	459	276	.044	6028	3626	1487	895
Bare Ground	.637	155	93	39	23	.109	2222	1337	557	335

1/ Expressed as the ratio of actual hits to the total number possible (700).

2/ N1 = Number of points required to sample within 10% of the population mean at the 90% confidence level.

N2 = Number of points required to sample within 10% of the population mean at the 80% confidence level.

N3 = Number of points required to sample within 20% of the population mean at the 90% confidence level.

N4 = Number of points required to sample within 20% of the population mean at the 80% confidence level.

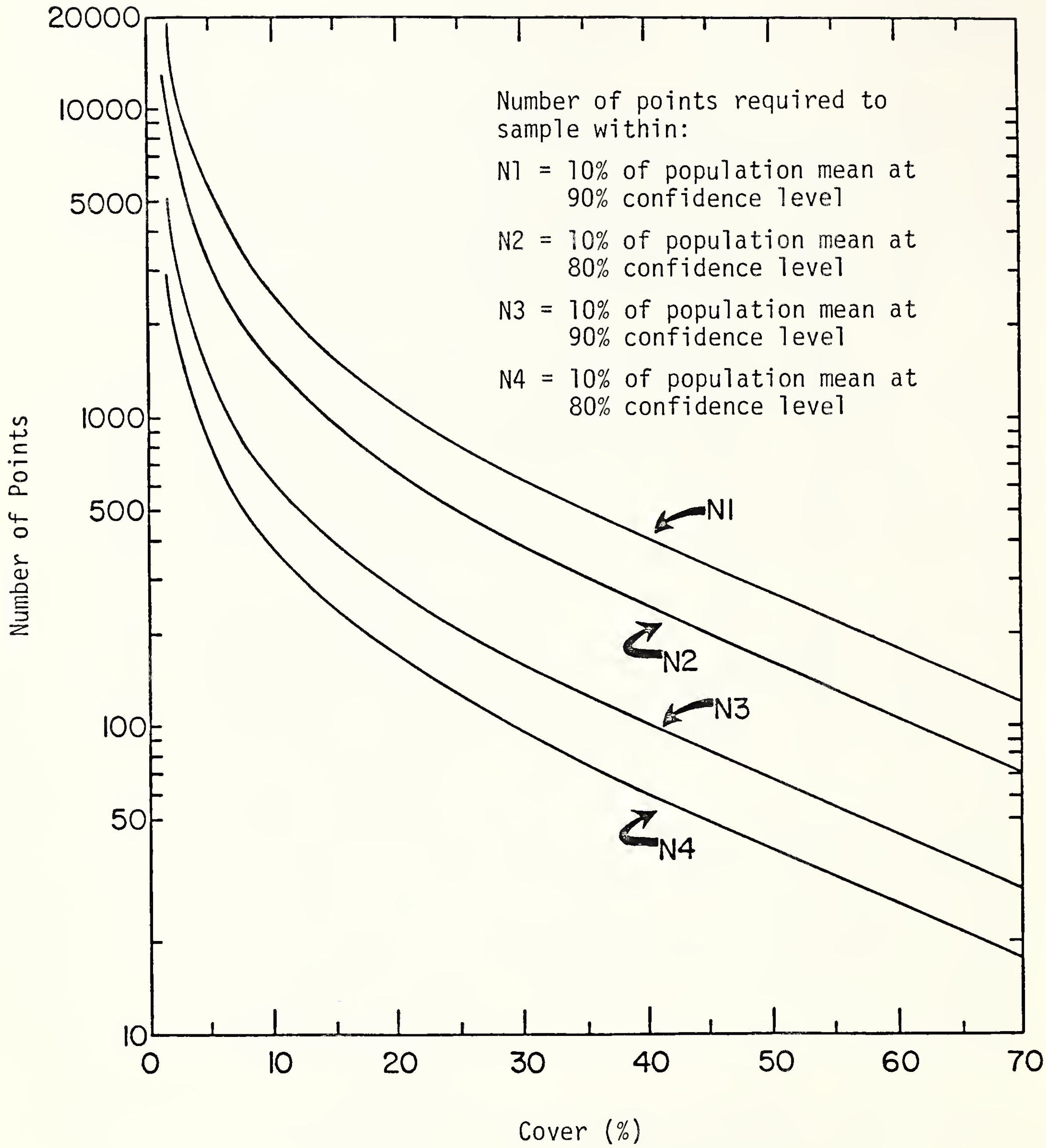

Figure 2.2.--Number of points required to measure cover in vegetation types represented by the Reynolds Creek Watershed.

Table 2.6.--Example of number of points required to determine that the difference in basal cover between two areas was statistically significant, based on 1975 measured data from the Nettleton site.

Cover Class	Basal Cover[1/]		Number of Points[2/]	
	No Grazing	Grazed	N1	N2
Grasses				
Cheatgrass	.239	.053	19	12
Sandberg bluegrass	.123	.131	9238	5686
Total	.396	.190	26	16
Forbs	.026	.017	1401	858
Shrubs	.030	.026	9068	5441
Total live cover	.451	.233	25	16
Litter	.396	.293	114	70
Rock	.044	.088	171	104
Bare ground	.109	.386	13	8

1/ The ratio of actual hits to total hits possible (700).

2/ N1 = Number of points needed in each study area to sample at the 90% level of confidence.

N2 = Number of points needed in each study area to sample at the 80% level of confidence.

Table 2.7.--Example of the number of weight estimates required to determine the vegetation yield (pounds/acre) at a sampling site.

	FLATS, 1977					FLATS, 1978				
	MEASURED MEAN YIELD	SAMPLE SIZE[1/]				MEASURED MEAN YIELD	SAMPLE SIZE			
		N1	N2	N3	N4		N1	N2	N3	N4
Grasses										
Bottlebrush Squirreltail	85	112	28	68	17	297	142	35	86	21
Total	101	72	18	43	11	720	93	23	56	14
Shrubs	162	451	113	272	68	1324	129	32	77	19
TOTAL YIELD	263	137	34	82	21	2061	61	15	37	9

	UPPER SHEEP, 1975					UPPER SHEEP, 1974				
	MEASURED MEAN YIELD	SAMPLE SIZE[1/]				MEASURED MEAN YIELD	SAMPLE SIZE			
		N1	N2	N3	N4		N1	N2	N3	N4
Grasses										
Needle-and-thread	21	269	67	161	40	169	134	33	81	20
Total	61	56	14	34	8	169	134	33	81	20
Shrubs	764	164	41	99	25	1188	106	26	64	16
TOTAL YIELD	1267	60	15	36	9	2105	32	8	19	5

1/ N1= number of weight-estimates required to sample within 10% of the population mean at the 90% confidence level.
N2= number of weight-estimates required to sample within 10% of the population mean at the 10 & 80% confidence level.
N3= number of weight-estimates required to sample within 10% of the population mean at the 20 & 90% confidence level.
N4= number of weight-estimates required to sample within 10% of the population mean at the 20 & 80% confidence level.

within 20 percent of the population mean, at the 80 percent level of confidence. If the sampling program requires a mean yield estimate within 10 percent of the population mean at the 90 percent level of confidence, about 250 weight-estimates would be required, and for some years, up to 450 weight-estimates would have to be obtained. In general, the least weight-estimate samples are required for total yield estimates, and the greatest number are required for shrubs and individual species.

These results indicate the high variability of range vegetation parameters. To effectively monitor trend, inventory samples should be adequately large enough to detect ecologically significant differences. Indicator species should be relatively abundant, as well as ecologically important. The problem of monitoring trend is further confounded by the variability of climate, and better techniques need to be applied to factor out climatic effects.

The wheel-point and step-point method produced similar results and could probably be used interchangeably. Both methods appear better adapted to routine trend analyses than the point-frame method.

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3. RUNOFF

Personnel Involved

C. W. Johnson, Research Hydraulic Engineer	Plans programs and procedures; designs and constructs facilities for runoff studies; performs analyses and summarizes results.
D. L. Brakensiek, Research Hydraulic Engineer	Streamflow and infiltration modeling.
A. L. Huber, Hydrologist	Runoff analyses and modeling.
C. L. Hanson, Agricultural Engineer rangelands.	Tests various components in runoff models most applicable to
G. R. Stephenson, Geologist	Groundwater.
J. P. Smith, Hydrologist	Streamflow data collection, quality control, processing, and analyses.
R. L. Engleman, Mathematician	Performs data compilation and assists in analysis.
R. P. Morris, and V. M. Aaron, Hydrologic Technicians	Performs data compilation and processing.
M. D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and radio telemetry systems.
K. R. Cooley, Hydrologist	Snowmelt runoff.
D. C. Robertson, Hydrologic Technician	Snowmelt runoff.

1981 WATER YEAR RUNOFF CONDITIONS

Watershed streamflows in the 1981 water year ranged from 53-102 percent of the average of record. Snow accumulation on March 15, 1981 was near the lowest of record for that date because the October-February precipitation was only about 50 percent of average at 6800 feet elevation. However, precipitation the last half of March and in April and May was 10-30 percent above average, resulting in peak streamflow rates in April at several stations.

MICROWATERSHEDS

Flats: No runoff was recorded at this station in 1981.

Nancy: The only significant event was from 0.32-inch of rain February 13-14 when the soil was frozen, which produced less than 0.01-inch of runoff from 3.1 acres.

SOURCE WATERSHEDS

Lower Sheep: Runoff from this 33-acre watershed was only 0.01-inch from 10 inches of precipitation, Table 3.1. Peak streamflow was about 0.1 ft /sec on February 14.

Reynolds Mountain East: Runoff from this 100-acre watershed at 6800 feet elevation was 9.94 inches, about 50 percent of the 19-year average. Precipitation was 65 percent of average, 26.38 inches, Table 3.1. The stream was dry during September and most of August, similar to the severe 1977 drought year.

Reynolds Mountain West: Runoff from this 126-acre watershed was 7.28 inches, about 47 percent of average, the third lowest of record, Table 3.1. Peak streamflow from rain and snowmelt April 20 was about two-thirds of average.

TRIBUTARY WATERSHEDS

Salmon Creek: Runoff from this 8,900-acre watershed was 2.22 inches from 18.38 inches of precipitation, about 75 percent of average runoff, Table 3.2. Peak streamflow from nearly 2 inches of rain April 18-20 was about 40 percent of average. April runoff was about double the average of record.

Macks Creek: Runoff from this 7,846-acre watershed was 1.46 inches, about 64 percent of average, Table 3.2. Peak streamflow was only 26 percent of average, and occurred February 14 from 0.57-inch of precipitation associated with snowmelt. Peak streamflow from rain April 20 was nearly as great as in February.

Dobson Creek: The station was discontinued in 1981.

Table 3.1. Water year precipitation, runoff, and peak streamflow, source watersheds, Reynolds Creek Watershed.

Water	Lower Sheep Watershed				Reynolds Mountain East Watershed				Reynolds Mountain West Watershed			
	Precipi-tation	Runoff	Peak Streamflow	Date of Peak	Precipi-tation	Runoff	Peak Streamflow	Date of Peak	Precipi-tation	Runoff	Peak Streamflow	Date of Peak
	inches	inches	ft^3/sec		inches	inches	ft^3/sec		inches	inches	ft^3/sec	
1963	16.98	---	---	---	37.82	11.11	4.16	Apr. 29	---2/	---	---	---
1964	13.55	---	---	---	40.89	21.02	3.60	May 16	---	---	---	---
1965	20.86	---	---	---	66.10	34.87	10.70	Dec. 23	---	25.00 1/	9.29	Dec. 23
1966	6.81	---	---	---	28.36	9.86	1.43	May 5	---	7.39	1.87	Apr. 8
1967	18.73	0.34 1/	1.41	Jan. 21	50.45	21.01	5.44	May 22	---	17.18	5.10	May 22
1968	11.30	0.02	0.08	Feb. 18	31.97	6.72	1.48	Aug. 10	---	6.31	1.97	Feb. 23
1969	14.12	0.52	0.49	Jan. 20	37.45	22.43	3.88	May 12	37.37	17.26	4.20	May 10
1970	14.24	0.02	0.05	Jan. 27	39.60	20.06	5.89	May 17	37.95	20.24	12.33	May 17
1971	17.68	0.31	0.20	Mar. 12	57.96	31.06	5.77	May 4	45.75	21.41	10.24	May 4
1972	13.82	0.91	2.08	Jan. 22	50.51	33.52	6.26	June 6	45.98	29.56	6.31	May 14
1973	12.20	0.01	0.02	Apr. 17	31.01	13.24	3.31	May 8	28.40	10.02	5.35	Apr. 27
1974	10.28	0.26	0.38	Mar. 15	45.54	26.64	4.33	May 7	38.67	19.77	5.61	May 7
1975	14.89	0.73	0.90	Feb. 13	51.57	27.93	9.27	June 2	42.83	21.24	14.28	June 2
1976	14.46	0.55	0.31	Mar. 17	42.51	22.35	4.59	May 13	---	16.38	4.09	May 2
1977	8.27	0	0	---	21.11	3.44	0.93	Apr. 16	---	2.31	0.72	Apr. 16
1978	15.13	0.14	0.09	Apr. 27	43.82	23.12	4.50	May 14	---	17.07	3.52	May 14
1979	9.90	0.34	1.33	Jan. 11	32.42	15.15	3.52	May 15	---	11.65	3.99	May 4
1980	15.00	0.01	0.09	Jan. 12	41.37	18.79	3.69	Apr. 22	---	13.33	4.22	Apr. 22
1981	10.02	0.01	0.10	Feb. 14	26.38	9.94	4.54	Apr. 20	---	7.28	3.83	Apr. 20
MEAN	13.59	0.30	0.53	---	40.89	19.59	4.59	---	---	15.49	5.70	---

1/ First complete year of record.

2/ Precipitation record began in 1968 and terminated in 1975.

Table 3.2. Water year precipitation runoff, and peak streamflow, Tributary Watersheds, Reynolds Creek Experimental Watershed.

	Salmon Creek			Macks Creek		
Water Year	Precipitation	Runoff	Peak Streamflow	Precipitation	Runoff	Peak Streamflow
	inches	inches	ft^3/sec	inches	inches	ft^3/sec
1963	22.63	---	---	---	---	---
1964	19.90	---	---	---	---	---
1965	33.51	9.65	1007	---	---	1200
1966	10.27	1.05	10	---	0.61	12
1967	22.77	2.24	85	---	1.54	90
1968	14.73	0.77	34	---	0.49	44
1969	19.36	3.14	209	19.90	2.93	307
1970	24.96	3.07	210	19.29	1.92	241
1971	24.34	3.61	132	23.65	3.79	281
1972	22.74	5.50	201	23.43	4.84	138
1973	17.35	2.14	55	15.93	1.76	54
1974	16.80	3.31	53	15.54	3.72	71
1975	20.43	3.54	92	22.68	4.79	142
1976	22.81	2.38	19	21.02	2.67	33
1977	12.83	0.62	103	14.67	0.43	19
1978	23.42	3.41	102	24.61	3.01	86
1979	17.63	2.25	380	16.45	2.10	300
1980	22.28	2.19	43	20.73	1.64	37
1981	18.38	2.22	69	15.69	1.46	47
MEAN	20.33	3.01	165	19.51	2.27	182

MAIN STEM WATERSHEDS

Reynolds Creek Outlet: Runoff from this 57,700-acre watershed was 1.40 inches, about 50 percent of the 19-year average, Table 3.3. Peak streamflow was about one-third of average from widespread rain April 18-20. Peak streamflow from rainfall and snowmelt February 13-16 was slightly less than in April. The irrigation water supply was less than one-half of average in May and June, Table 3.4.

Reynolds Creek Tollgate: Runoff from this 13,453-acre watershed was 4.58 inches, about 57 percent of the 16-year mean, Table 3.3. Peak streamflow was 169 ft^3/sec on February 16 from snowmelt and rain with frozen soil. April 20 peak streamflow was 149 ft^3/sec. Precipitation was about 75 percent of the 19-year mean. Monthly runoff during May-July was only one-third of the average during this critical irrigation period, Table 3.4. However, crop yields in Reynolds valley were near or above normal because of favorable March-June rain.

Table 3.3. Water year precipitation, runoff, and peak streamflow for main stem watersheds.

	Reynolds Creek Outlet				Reynolds Creek at Tollgate			
Water	Precipi-tation 1/	Runoff	Peak Streamflow	Date of Peak	Precipi-tation 2/	Runoff	Peak Streamflow	Date of Peak
	inches	inches	ft^3/sec		inches	inches	ft^3/sec	
1963	25.03	1.85	2331	Jan. 31	31.07	---	---	---
1964	15.25	2.45	188	Jan. 25	24.25	---	---	---
1965	26.83	7.05	3850	Dec. 23	38.93	---	1100 3/	---
1966	9.05	0.76	59	Apr. 1	13.79	3.55	59	Apr. 1
1967	19.68	2.19	265	June 7	28.10	9.09	288	June 7
1968	14.20	0.61	327	Feb. 21	21.51	3.08	186	Feb. 21
1969	16.85	3.60	900	Jan. 21	29.11	11.47	405	Jan. 21
1970	20.13	2.70	729	Jan. 27	31.35	9.64	240	Jan. 27
1971	24.96	4.78	540	Jan. 18	41.89	14.98	196	May 6
1972	22.13	6.07	678	Mar. 2	38.12	16.45	271	Mar. 2
1973	16.19	1.85	166	Apr. 17	25.18	6.00	147	Apr. 17
1974	17.14	4.37	291	Mar. 29	29.53	12.75	195	Mar. 29
1975	19.57	4.12	281	Mar. 25	31.18	13.31	231	June 2
1976	20.34	2.84	140	Apr. 5	29.90	10.05	130	May 10
1977	11.41	0.35	1119	June 11	15.49	1.51	17	Apr. 8
1978	19.64	3.29	589	Apr. 26	28.98	11.32	230	Apr. 26
1979	14.56	2.06	1662	Jan. 11	20.19	6.78	121	Jan. 11
1980	18.51	2.26	259	May 6	29.08	8.15	163	Apr. 23
1981	14.40	1.40	251	Apr. 20	20.91	4.58	169	Feb. 16
MEAN	18.25	2.87	770		27.82	8.91	191	

1/ Raingage No. 116X91.
2/ Raingage No. 155X07.
3/ Estimated peak flow.

Table 3.4. Water year runoff in 1981 and the mean of record by months.

Month	Reynolds Creek Outlet Runoff		Reynolds Creek Tollgate Runoff	
	1981	1963-1981	1981	1966-1981
	--------inches--------			
October	.029	0.025	.076	0.082
November	.038	0.046	.083	0.121
December	.099	0.161	.211	0.218
January	.078	0.380	.129	0.551
February	.225	0.271	.452	0.422
March	.145	0.455	.405	0.965
April	.382	0.550	1.673	1.788
May	.248	0.609	1.157	3.088
June	.120	0.296	.343	1.358
July	.024	0.048	.050	0.234
August	.012	0.022	.001	0.046
September	.003	0.013	.001	0.037
Total	1.403	2.876	4.581	8.910

INFILTRATION BASED RUNOFF ESTIMATION

INTRODUCTION

When compared with the SCS curve number procedure for runoff prediction, the infiltration approach requires significantly more input data and a much more complex computational methodology. However, the general availability of soil and soil water data is increasing the feasibility of the infiltration approach. The infiltration approach also enhances our ability to evaluate the effects that land use practices and treatments have on the generation of runoff.

Table 3.5 compares the factors in the SCS runoff equation procedure with the infiltration procedure. Factors correspond to those that are described in the SCS National Engineering Handbook, Section 4-Hydrology, Tables 4.2 and 9.1, and Fig. 10 (1972). The Precipitation Factor required in the infiltration approach is a rainfall distribution and amount, as compared to the simple amount. The Soil Factor under the infiltration approach represents the initial soil-water condition and the soil infiltration equation parameters. Cover Factors represent the influence that land use and soil surface practices have on the infiltration equation. This influence is assumed to relate to soil hydraulic properties, such as soil porosity, and the antecedent water content. Surface storages, surface interception and surface depressions, are determined by surface cover and surface practices, as discussed by Dunne and Leopold (1978).

The infiltration approach presented here applies the Green and Ampt infiltration equation to the SCS Type II, 24-hour rainfall distribution. Table 3.6 presents the 24-hour rainfall intensity and accumulation distributions, respectively (Kent, 1968).

Table 3.7 presents the estimates for the Green and Ampt parameters. These values were developed in studies by Rawls et al. (1981). The infiltration approach must be applied in two stages during the rainfall event, i.e., pre-ponding and post-ponding. Prior to surface ponding, the infiltration rate is the rainfall rate minus the surface interception rate and, thus, is generally rainfall dependent. After surface ponding, the infiltration rate is determined by soil properties as long as rainfall excess continues. The two stages are linked by a time correction, which is applied to the rainfall time scale.

Table 3.5.--Comparison of direct runoff prediction approaches.

Factors	Approach: Curve Number[1/]	Approach: Infiltration
Precipitation:	Rainfall amount (24-hr)	Rainfall intensities or rainfall distribution and amount
Soil	Antecedent Moisture Condition (I, II, or III) (5-day prior rainfall)	Antecedent soil-water storage (volume) by soil layers or soil depth
	Hydrologic Soil Group (HSG) (A, B, C, or D)	Soil-water properties by layers or soil depth, i.e., bulk density, saturated conductivity, and soil-water entry or bubbling pressure
Cover	Land use Treatment or Practice Hydrologic condition	Influences on soil properties by: Tillage Amendments Traffic/animal compaction Crusts, desert pavement Mulch cover Vegetation cover
Storage:		
Soil	Initial abstraction (I_a), assumed as 0.2 (S)	Infiltration prior to surface ponding
Surface	Included with initial abstraction, I_a	Estimated surface depressional storage as influenced by topography and land use
Interception	Included with initial abstraction, I_a	Estimated interception storage by ground cover (live and/or mulch)

1/ The factors under the Curve Number Approach are taken from Table 9.1 and Figure 10.1, SCS National Engineering Handbook, Section 4 - Hydrology.

Table 3.6.--SCS Type II, 24-hour duration rainfall distribution.

Time	Accumulated rainfall amount/ 24-hr total	Rainfall intensity/ 24-hr total	Time	Accumulated rainfall amount/ 24-hr total	Rainfall intensity/ 24-hr total
T	PA	PI	T	PA	PI
(hr)	--	(hr^{-1})	(hr)	--	(hr^{-1})
0.00	.000	--	12.0	.6632	.7598
.5	.0053	.0106	12.5	.7351	.1438
1.0	.0108	.0110	13.0	.7724	.0746
1.5	.0164	.0112	13.5	.7989	.0530
2.0	.0223	.0118	14.0	.8197	.0416
2.5	.0284	.0122	14.5	.8380	.0366
3.0	.0347	.0126	15.0	.8538	.0316
3.5	.0414	.0134	15.5	.8676	.0276
4.0	.0483	.0138	16.0	.8801	.0250
4.5	.0555	.0144	16.5	.8914	.0226
5.0	.0632	.0154	17.0	.9019	.0210
5.5	.0712	.0160	17.5	.9115	.0192
6.0	.0797	.0170	18.0	.9206	.0182
6.5	.0887	.0180	18.5	.9291	.0170
7.0	.0984	.0194	19.0	.9371	.0160
7.5	.1089	.0210	19.5	.9446	.0150
8.0	.1203	.0228	20.0	.9519	.0146
8.5	.1328	.0250	20.5	.9588	.0138
9.0	.1467	.0278	21.0	.9653	.0130
9.5	.1625	.0316	21.5	.9717	.0123
10.0	.1808	.0366	22.0	.9777	.0120
10.5	.2042	.0468	22.5	.9836	.0118
11.0	.2351	.0618	23.0	.9892	.0112
11.5	.2833	.0964	23.5	.9947	.0110
12.0	.6632	.7598	24.0	1.0000	.0106

Table 3.7.--Green and Ampt infiltration equation parameters - mean values for each soil texture class.

Soil Texture	Total Porosity	Effective Porosity	Wetted Front Capillary Pressure	Conductivity
		PO	WF	K
	(-)	(-)	(cm)	(cm/hr)
Sand	0.438	0.417	4.95	11.78
Loamy Sand	.437	.401	6.13	2.99
Sandy Loam	.453	.412	11.01	1.09
Loam	.463	.434	8.89	.340
Silt Loam	.501	.486	16.68	.648
Sandy Clay Loam	.398	.330	21.85	.153
Clay Loam	.464	.390	20.88	.097
Silty Clay Loam	.471	.432	27.30	.097
Sandy Clay	.430	.321	23.90	.064
Silty Clay	.479	.423	29.22	.051
Clay	.475	.385	31.63	.034

In the following sections, the procedures are developed and, by examples, are illustrated for predicting the surface runoff amount for the 24-hr, SCS Type II rainfall distribution with the Green and Ampt infiltration equation. The specific computational procedures are available in a BASIC computer program written for an APPLE II Plus with 48 K RAM and one DISC[1/]. The basis of the procedure is an iterative solution of the developed equations with the tabulated rainfall distribution values in Table 3.6. Estimates of peak runoff rates can be made from the predicted runoff volume and duration utilizing the procedure in Kent (1968), or the equation developed by Smith and Williams (1980).

PRE-PONDING INFILTRATION

Time to ponding

At the time of surface ponding, the infiltration rate equals the rainfall rate. The amount of infiltration up to that time is the accumulated rainfall minus interception storage. At that time the Green and Ampt infiltration equation is written as:

$$f = p = K[1 + n WF/(P-SI)] \qquad [1]$$

where

f = infiltration rate, cm/hr

p = rainfall intensity, cm/hr

P = accumulated rainfall, cm

SI = surface interception, cm

K = conductivity, cm/hr (Table 3.7)

n = available soil porosity, effective porosity reduced by antecedent soil-water = (PO-AW)

WF = matric pressure at the wetting front, cm (Table 3.7)

PO = effective porosity (Table 3.7)

AW = antecedent soil water

1/ Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the U.S. Department of Agriculture.

Since the rainfall rates and amounts are tabulated (Table 3.6) as a ratio to the 24-hour amount, P2, equation [1] is re-written as:

$$P2(PI) = K\left(1 + \frac{OM}{P2(PA-SI/P2)}\right) \qquad [2]$$

where

$OM = WF(PO-AW)$

$PI = p/P2$, hr^{-1}, the intensity ratio

$PA = P/P2$

$P2$ = total 24-hr rainfall, cm

OP = effective porosity

SI = surface interception

Multiplying both sides of [2] by P2/K(OM) gives:

$$\frac{(P2)}{K(OM)}(PI) = \frac{P2}{OM} + \frac{1}{(PA-SI/P2)}$$

or

$$(PS)^2[\alpha(PI)] - PS - \frac{1}{(PA-SI/P2)} = 0 \qquad [3]$$

where

$PS = P2/OM$

$\alpha = OM/K$

Solving for PS gives

$$PS = \frac{1 + \sqrt{1 + 4\ (PI)/(PA-SI/P2)}}{2\ (PI)} \qquad [4]$$

Equation [4] is solved by an iterative procedure using Table 3.6. The time at which the Right Hand Side (RHS) of equation [4] equals the known Left Hand Side (LHS) of [4] is the time the infiltration rate equals the rainfall rate. Inputs are rainfall amounts and intensity ratios, PA and PI, the soil texture, the antecedent soil water content, and the 24-hour rainfall amount. Computation restrictions placed on SI and DS are:

$$SI < 0.66(P2)$$

$$DS \leq P2$$

Time correction

After surface ponding, the infiltration rate proceeds at the maximum rate which the soil will sustain until the rainfall rate falls below the infiltration rate. The integrated form of the Green and Ampt equation then applies:

$$FC - (OM)\ell n(1 + \frac{FC}{OM}) = KT \qquad [5]$$

where FC is the accumulated infiltration amount, T is time, and (OM) and K are the parameters defined for equation [1]. However, the time scale in [5] must be adjusted for the pre-ponding time period, i.e., initialized to the start of rainfall. The time correction was developed by Mein and Larson (1971). The correction for the time scale is:

$$TC = (TP - TE) \qquad [6]$$

where TP is the time to ponding and TE is the equivalent time for the pre-ponding infiltration if it had occurred with ponded conditions.

Calculation of TE is facilitated by an approximation of equation [5] derived by Li et al. (1976):

$$TE = (F1)^2/[K(2(OM) + F1)] \qquad [7]$$

where F1 is the infiltration amount at ponding <u>exclusive</u> of surface interception.

POST-PONDING INFILTRATION

Infiltration rates and amounts

After ponding the approximation derived by Li et al. (1976) is used to calculate accumulated infiltration

$$FC = (OM/2)\left(TT + \sqrt{TT(8. + TT)}\right) \qquad [8a]$$

where $TT = (T - TC)/\alpha$

$\alpha = OM/K$

The infiltration rate is calculated as:

$$F = K(1 + OM/FC) \qquad [8b]$$

where F = infiltration rate, cm/hr

Cessation of Rainfall Excess

At the termination of rainfall excess, the infiltration rate again equals the rainfall rate:

$$p = K(1 + OM/FC)$$

or

$$\frac{P2}{K}(PI) = 1 + \frac{1}{(FC/OM)}$$

or

$$PS\ (\alpha PI) = 1 + 1/FS \qquad [9]$$

where $FS = FC/OM$

$PS = P2/K$

$PI = p/P2$

Solving [9] for FS gives:

$$FS = 1/[PS\ (\alpha PI) - 1] \qquad [10]$$

Equation [10] represents the total amount of infiltration that reduces the infiltration rate to the appropriate rainfall rate. Substituting equation [10] into the Li approximation (equation [7]) and solving for PS gives, after simplification:

$$PS = \frac{1}{4\alpha(PI)} \left[3 + \sqrt{1 + \frac{8\alpha}{T-TC}} \right] \qquad [11]$$

where $\alpha = OM/K$

Time in [11] is limited to the interval:

$$12 < T < 24$$

Equation [11] is also used with an iterative procedure and Table 3.6 to interpolate the time at which the rainfall rate equals the infiltration rate, i.e., when the right hand side equals the left hand side.

DISCUSSION

The application of the runoff procedures is illustrated with the examples presented in the following section. In Figures 3.1 and 3.2, the flow charts present principal computational segments of the program. The SCS Type II rainfall distribution resides in the program; however, other 24-hour distributions could be substituted. Soil inputs are given in Table 3.7 by soil texture. The 24-hour rainfall total is program input.

Equation [4] is the basis for calculating the time of ponding, TP. In principle, values of accumulated rainfall ratios, PA, and rainfall intensity ratios, PI, for succession times, T, in Table 3.6 are substituted in the Right Hand Side (RHS) of equation [4] and its values compared with the known Left Hand Side (LHS). The lower and upper bound times are established, which bracket the LHS of equation [4]. A linear interpolation equation is then used to calculate the ponding time. If surface ponding does not occur by the end of the initial 12 hours, then no rainfall excess occurs. Note that surface interception, SI, is excluded from rainfall, as it does not contribute to soil infiltration. From the ponding time, the infiltration at ponding can be calculated. The time correction, equation [6], is calculated. Soil surface storage filled during the initial 12 hours is also calculated. Figure 3.3 shows the time positioning of these calculated quantities for the first example. Calculations for a second example are presented to show a situation where depressional storage is not filled in the initial 12 hours.

Following surface ponding and during the period of rainfall excess, infiltration amounts can be calculated using equation [8a] and rates by equation [8b]. The rate curve is plotted in Fig. 3.3 starting at ponding.

The second half of the program uses the final 12 hours of the rainfall distribution input (Table 3.6). Equation [11] is the basis for calculating the cessation of rainfall excess. By substituting sucessive values of PI and Time from Table 3.6, a lower and upper bound is established whereby the Right Hand Side of [11] brackets the known Left Hand Side of [11]. Again, a linear interpolation equation calculates the Time that rainfall excess ends, TX. The total rainfall excess is then calculated and soil surface storage is filled by available rainfall excess. If soil surface storage is filled, then surface runoff is calculated and its duration is determined. If the surface storage component is not filled by rainfall excess, then no surface runoff is calculated.

The output listing for the examples show the calculated quantities. Figure 3.3 shows the corresponding time sequence of the calculated quantities for example 1. Table 3.8 presents a list of symbols used for input, computations, and output.

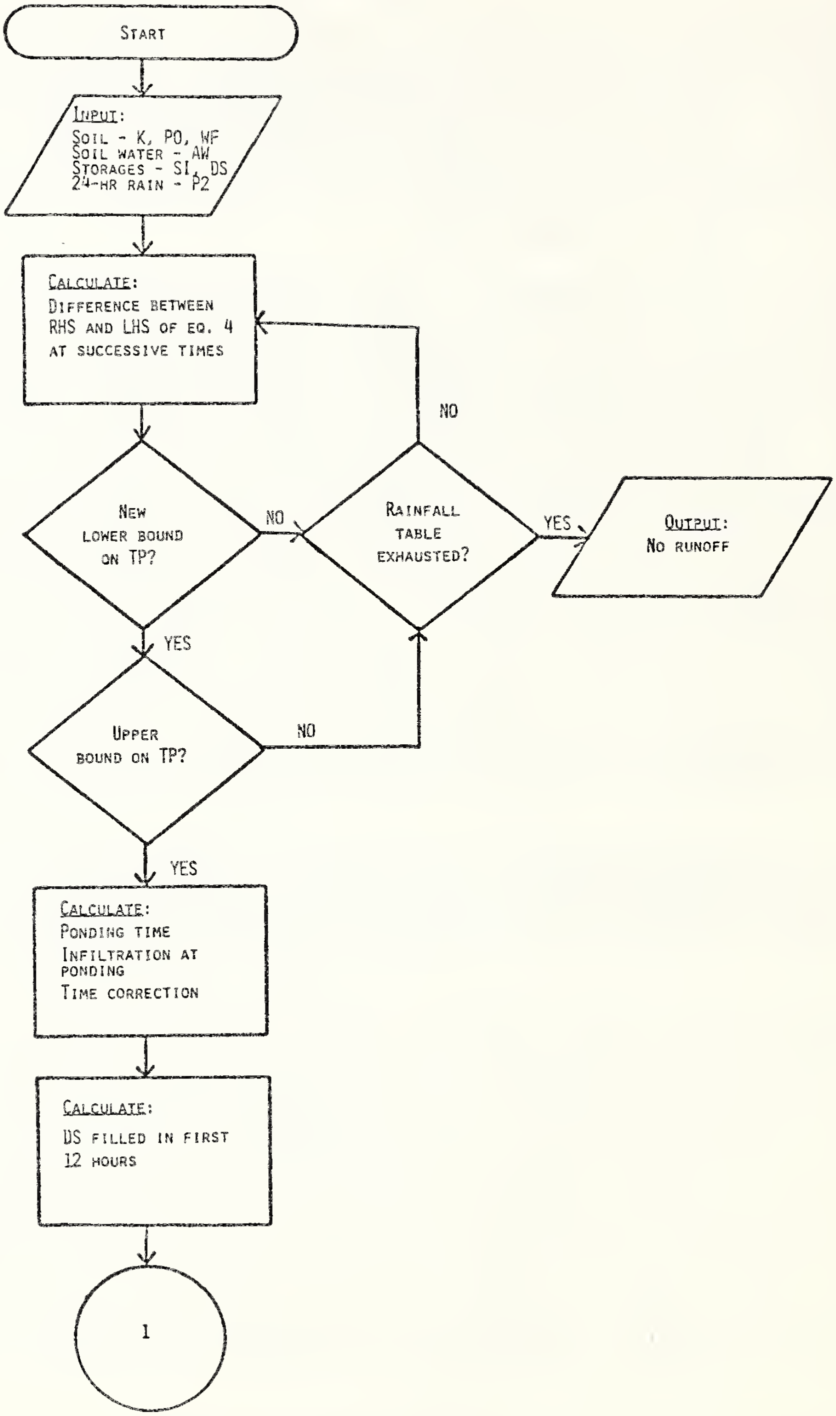

Figure 3.1.--Initial 12 hours of rainfall.

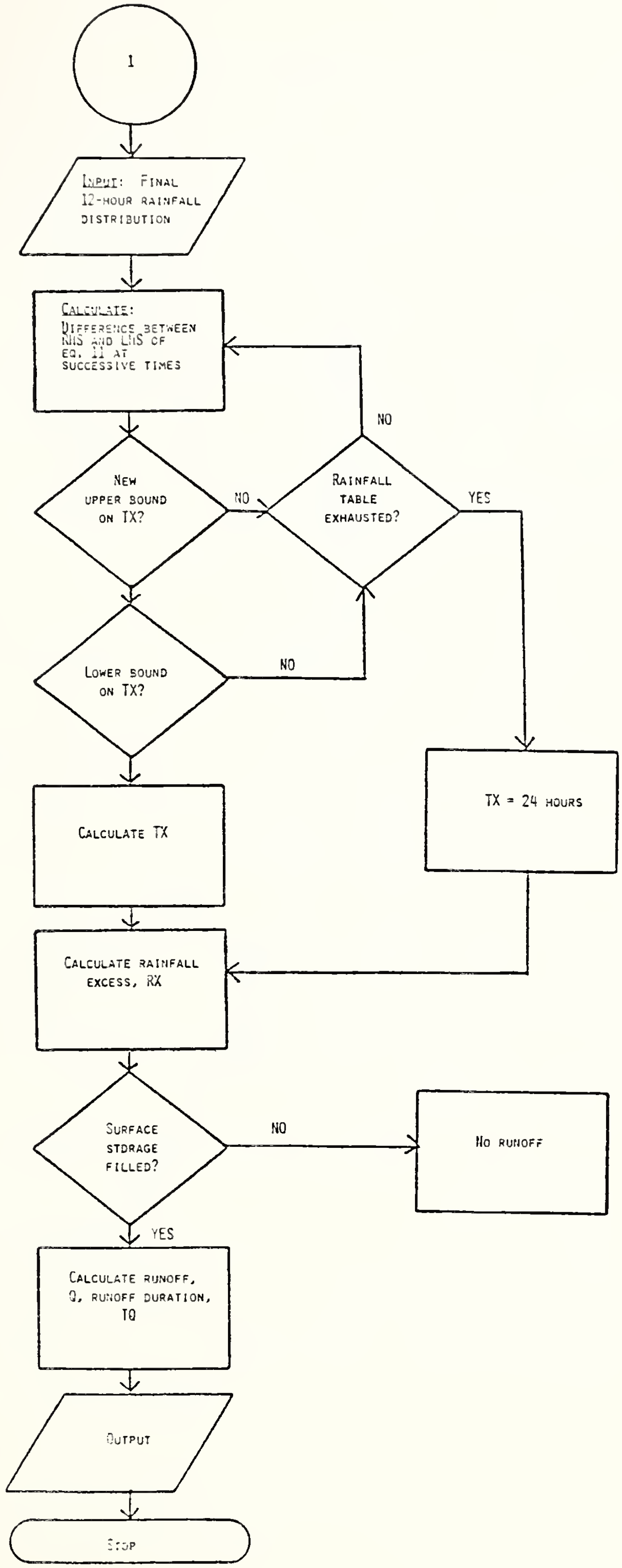

Figure 3.2.--Final 12 hours of rainfall.

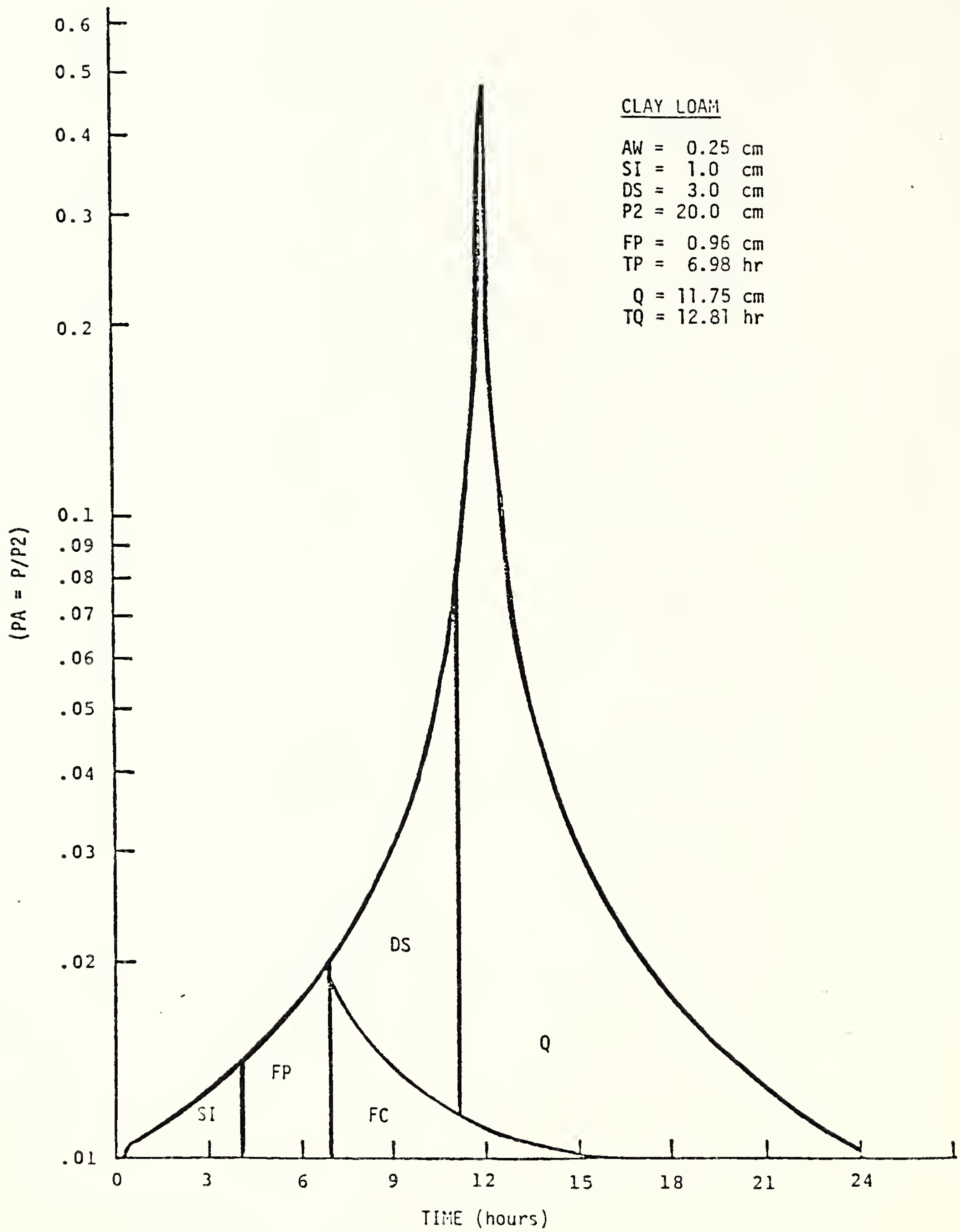

Figure 3.3.--Example 1.

EXAMPLES

(1) SOIL TEXTURE: Clay Loam

INPUTS: K = 0.097 cm/hr, AW = 0.25, PO = 0.390,
WF = 20.88 cm, SI = 1.0 cm, DS = 3.0 cm,
P2 = 20 cm

OUTPUTS:

FP = 1.96 cm	TP = 6.98 hr	
F1 = 0.96 cm	T1 = 2.86 hrs	
SI = 1.0 cm	ST = 4.12 hrs	
DS = 3 cm	TD = 11.19 hrs	
RX = 20.0 cm	TX = 24.0 hrs	FT = 4.246 cm

Runoff is produced:

Q = 11.75 cm TQ = 12.81 hr.

(2) SOIL TEXTURE: Sand

INPUTS: K = 11.688 cm/hr, AW = 0.25, PO = .417, WF = 4.95 cm,
SI = 1.0 cm, DS = 5.0 cm, P2 = 30. cm

OUTPUTS:

FP = 16.93 cm	TP = 11.87 hr	
F1 = 15.93 cm	T1 = 8.98 hr	
SI = 1.0 cm	ST = 2.89 hrs	
DS = 5.0 cm	TD = 12.14 hours	
RX = 20.49 cm	TX = 12.14 hr	FT = 19.08 cm

Runoff is not produced:

Q = 0 DS (FILLED) = 0.41 cm

Table 3.8.--Input and output parameters.

Rainfall Distribution Input (Table 3.6)	
PA	Tabular accumulated rainfall amounts divided by 24-hour total
PI	Tabular rainfall intensities divided by 24-hour total, hr^{-1}
T	Tabular time, hr
Soil, Storage and Storm Input	
K	Green-Ampt conductivity, cm/hr
AW	Antecedent water content, cm^3/cm^3
PO	Effective porosity, total porosity minus residual saturation, cm^3/cm^3
WF	Green-Ampt wetting front suction, cm
SI	Surface interception, cm (must be less than 66% of 24-hour rainfall)
DS	Soil surface storage, cm (must be less than 24-hour rainfall)
P2	24-hour rainfall total, cm
Output	
FP	Infiltration total at surface ponding, including surface interception, cm
F1	FP minus SI
TP	Time at surface ponding, hrs
T1	TP minus time to fill SI
SI	Surface interception, cm
ST	Time at which surface interception is filled, hr
DS	Surface storage, cm
TD	Time at which surface storage is filled, hr
RX	Total rainfall excess, cm
TX	Duration of RX, hr
FT	Total infiltration, cm
Q	Surface runoff volume, cm
TQ	Duration of Q, hr

CONCLUSIONS

Equations are presented for applying the Green and Ampt infiltration equation to an SCS Type II (24-hour) rainfall distribution. Other 24-hour distributions, as well as a constant intensity distribution, can be placed in the program and runoff calculated. Soil inputs for the infiltration parameters are included. The predicted runoff amounts and durations can be utilized in making peak rate estimates.

For design situations, the infiltration approach provides an improved framework for evaluating the effects of land use and practices on runoff amounts and duration. For example, changes in soil porosity can be directly entered as an infiltration equation parameter. The availability and ease of operation of micro-computers enables the practicing hydrologist to utilize runoff models, such as the one reported here.

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4. EROSION AND SEDIMENT

Personnel Involved

C. W. Johnson, Research Hydraulic Engineer	Plans programs and procedures; designs and constructs facilities for sediment studies; performs analyses and summarizes results.
G. R. Stephenson, Geologist	Determines geologic and geomorphic parameters related to sediment yield.
C. L. Hanson, Agricultural Engineer	Tests various components in sediment models most applicable to rangelands.
R. L. Engleman, Mathematician	Performs data compilation and assists in analyses.
J. P. Smith, Hydrologist	Data collection, compilation, and analyses.
S. P. Belknap, Scientific Aid (U. of Idaho Cooperator)	Data collection.
A. P. Veigel, Biological Technician (U. of Idaho Cooperator)	Sediment analysis.
M. D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and radio telemetry systems.

Reynolds Creek (Reynolds Creek Experimental Watershed station locations are shown in the Introduction, Figure 1).

MICROWATERSHEDS

Flats: No runoff or sediment yield in 1981.

Nancy Gulch: Insignificant sediment yield in 1981.

SOURCE WATERSHED

Reynolds Mountain East: Total sediment yield from this 100-acre watershed in 1981 was 10.1 tons, 78 percent of the 14-year mean, Table 4.1. The maximum suspended sediment concentration was 565 mg/l with peak streamflow.

TRIBUTARY WATERSHED

Macks Creek: Suspended sediment yield from this 7,846-acre watershed was 143 tons, only 7 percent of the 14-year mean, Table 4.1. Nearly 70 percent of 1981 sediment yield was on February 14, and April 20. The maximum suspended sediment concentration was 1,990 mg/l on February 14.

MAIN STEM WATERSHEDS

Reynolds Creek at Outlet: Suspended sediment yield from the 57,754-acre watershed was 1,867 tons in 1981, 15 percent of the 15-year mean, Table 4.1. About 88 percent of the sediment yield was from snowmelt associated runoff in February and April. The maximum suspended sediment concentration was about 6,000 mg/l on April 20.

Reynolds Creek at Tollgate: Total sediment yield from this 13,453-acre watershed was 1,340 tons, 27 percent of the 15-year mean, Table 4.1. About 85 percent of the sediment yield was produced in peak runoff periods in February and April. The maximum suspended sediment concentration was about 6,000 mg/l with peak streamflow February 16.

VEGETATION GROUND COVER ANALYSIS AND PREDICTION

Percent bare ground at peak standing crop, as an indicator of erosion potential, ranged widely from year-to-year on vegetation study sites on the Reynolds Creek Experimental Watershed, Table 4.2. The objective of this study was to predict on April 1 of each year, the percent bare ground at peak standing crop based on:

Table 4.1.--Sediment yield in tons at Reynolds Creek Watershed Stations.

Year	Reynolds Mountain East	Macks[1/] Creek	Reynolds Creek at Tollgate	Reynolds[1/] Creek at Outlet
1967	---	---	11275	13503
1968	5.5	393	1965	4334
1969	17.0	6332	12994	39336
1970	31.1	3585	7242	15369
1971	18.1	5833	9771	28641
1972	18.3	5414	8838	37396
1973	9.4	1147	1203	2415
1974	10.3	1214	2774	5762
1975	14.2	1949	7867	9860
1976	12.4	646	2546	1430
1977	1.0	7	51	3257
1978	12.1	554	2797	8256
1979	9.2	1634	1808	11674
1980	12.7	87	1778	4237
1981	10.1	143	1340	1867
MEAN	13.0	2067	4950	12489

1/ Suspended sediment only.

Table 4.2.--Percent bare ground at peak standing crop (PSC), Reynolds Creek Watershed vegetation study sites.

Site		1972	1973	1974	1975	1976	1977	1978	1979	1980
		percent bare ground								
057	Ungrazed	40.6	54.6	34.8	69.2	89.7	44.8	55.6	39.4	22.1
	Grazed	39.3	54.3	39.0	63.4	77.0	62.5	67.1	61.1	42.6
092	Ungrazed	--	37.0	26.6	26.8	31.8	35.8	27.0	29.8	12.4
	Grazed	--	29.7	33.0	29.4	23.9	34.6	37.6	37.0	24.2
098	Ungrazed	31.7	54.6	32.9	38.2	23.6	30.5	46.2	40.5	22.6
	Grazed	21.9	54.3	35.4	48.5	23.8	36.0	47.3	43.1	29.3
135	Ungrazed	16.7	24.8	17.9	11.9	12.0	24.0	14.5	11.8	10.4
	Grazed	16.9	35.8	30.6	38.7	21.9	33.0	33.0	39.1	27.2
117	Ungrazed	16.8	--	26.8	25.7	8.1	26.1	14.5	32.9	17.3
	Grazed	15.4	--	27.3	31.8	6.9	38.1	33.0	28.2	15.6
138N	Ungrazed	5.4	14.3	11.5	6.9	7.8	15.0	3.3	3.0	1.2
	Grazed	9.3	18.0	17.5	15.6	22.0	11.7	18.0	17.4	7.0
138S	Ungrazed	18.1	--	32.0	40.1	36.4	51.7	40.0	47.8	32.4
	Grazed	26.9	--	48.1	47.0	26.6	65.0	41.4	54.8	41.4
176E	Ungrazed	11.5	17.1	24.6	19.6	13.0	15.6	15.6	21.8	18.8
	Grazed	13.9	19.8	23.2	23.6	29.4	21.8	16.6	27.0	29.2
176W	Ungrazed	11.2	--	17.7	24.4	14.3	45.5	17.1	11.1	7.0
	Grazed	19.9	--	24.7	29.9	6.4	46.3	16.7	21.6	14.4

1. The percent bare ground at peak standing crop the previous year.

2. The percent of the area not protected by overstory vegetation at peak standing crop the previous year.

3. The accumulated precipitation in inches at the site during the previous 6-month period, October-March.

4. Estimated precipitation in inches during the April-July growing season of the current year.

A precipitation analysis showed no significant persistence between precipitation amounts in the October-March winter precipitation accumulation period, and amounts in the following April-July period when most vegetative growth occurs. Consequently, no estimates were made of April-July precipitation.

The generalized form of the multiple regression equation used in the analysis of bare ground data was:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3$$

where Y is the dependent variable, percent bare ground at peak standing crop of the current year; X_1 is an independent variable, percent bare ground at peak standing crop the previous year; X_2 is an independent variable, the percent of the area without overstory canopy; and X_3 is an independent variable, the accumulated precipitation during the previous 6-month period October-March; and b_0, b_1, b_2, and b_3 are regression coefficients. Regression equations developed in the analysis are summarized in Table 4.3. The coefficients of multiple regression are a measure of the degree of association between observed and predicted values of percent bare ground at each site, and results range from excellent to poor for the period of study. Overall, predictions of percent bare ground are better for ungrazed areas.

Further improvement in April 1 predictions of percent bare ground, Y, was attempted using percent bare ground at the end of the grazing season, instead of at peak standing crop, X_1. Equations and correlation coefficients from this analysis are shown in Table 4.4. Since data were collected at the end of the grazing season for only four years of the 9-year study period, equations were not developed for individual sites. Overall, use of data collected at the end of the grazing season slightly improved the predictions.

The procedure used in this study has application in managing rangelands through drought and wet years when potential erosion ranges widely. Also, the procedure could be useful in trend plot analysis for sites with a good historical record of bare ground data.

Table 4.3.--Regression equations developed for individual vegetation sites on the Reynolds Creek Experimental Watershed, 1972-80 data at peak standing crop (PSC).

Site	Equation	r [1/]
057 Ungrazed	$Y = -36.30 + 0.70X_1 - 0.49X_2 + 13.59X_3$	0.66
057 Grazed	$Y = 10.25 + 0.64X_1 - 0.34X_2 + 5.15X_3$	0.46
092 Ungrazed	$Y = 20.32 + 0.48X_1 - 0.68X_2 - 0.02X_3$	0.47
092 Grazed	$Y = 35.16 + 0.12X_1 + 0.07X_2 - 0.75X_3$	0.49
098 Ungrazed	$Y = 40.14 - 0.62X_1 + 0.44X_2 + 1.78X_3$	0.44
098 Grazed	$Y = 53.19 - 1.10X_1 + 0.62X_2 + 2.31X_3$	0.81
117 Ungrazed	$Y = 36.97 - 1.03X_1 + 0.70X_2 + 0.02X_3$	0.73
117 Grazed	$Y = 44.90 - 0.25X_1 + 0.86X_2 - 3.65X_3$	0.68
135 Ungrazed	$Y = 10.44 + 1.47X_1 - 0.82X_2 - 0.90X_3$	0.71
135 Grazed	$Y = 45.20 - 0.38X_1 + 0.05X_2 - 0.11X_3$	0.54
138N Ungrazed	$Y = 15.18 - 0.31X_1 + 2.16X_2 - 1.04X_3$	0.73
138N Grazed	$Y = 10.84 + 0.27X_1 - 1.09X_2 + 0.93X_3$	0.70
138S Ungrazed	$Y = 48.69 + 0.50X_1 - 0.84X_2 - 1.19X_3$	0.97
138S Grazed	$Y = 80.52 - 0.53X_1 + 0.84X_2 - 3.68X_3$	0.99
176E Ungrazed	$Y = 20.02 - 0.47X_1 + 1.23X_2 + 0.05X_3$	0.67
176E Grazed	$Y = 15.48 + 0.24X_1 - 0.04X_2 + 0.12X_3$	0.33
176W Ungrazed	$Y = 60.56 - 1.66X_1 + 3.57X_2 - 2.71X_3$	0.70
176W Grazed	$Y = 54.55 - 1.84X_1 + 2.18X_2 - 1.05X_3$	0.80
ALL Ungrazed	$Y = 14.40 + 0.43X_1 + 0.34X_2 - 0.36X_3$	0.70
ALL Grazed	$Y = 24.88 + 0.34X_1 + 0.17X_2 - 0.51X_3$	0.62

[1/] Coefficient of multiple correlation.

Table 4.4.--Regression equation developed from data collected at the end of the grazing season (EGS) compared with data collected at peak standing crop (PSC); data from 1974, 1975, 1978, and 1979 used in both analyses.

Data Base	Equation	r
PSC Ungrazed	$Y = -.26 + 1.11X_1 - 0.30X_2 - 0.06X_3$	0.76
PSC Grazed	$Y = 3.34 + 0.68X_1 + 0.20X_2 + 0.04X_3$	0.69
EGS Ungrazed	$Y = 11.34 + 1.64X_1 - 0.96X_2 - 0.57X_3$	0.78
EGS Grazed	$Y = 14.21 + 1.01X_1 - 0.35X_2 - 0.25X_3$	0.74

SOIL LOSS STUDIES

The Universal Soil Loss Equation (USLE) is

$$A = RKLSCP$$

where A is the computed soil loss per unit area; R is the rainfall and runoff factor; K is the soil erodibility factor; L is the slope-length factor; S is the slope-steepness factor; C is the cover and management factor; and P is the support practice factor (Wischmeier and Smith, 1978). Application of this equation to prediction of soil losses from sagebrush rangelands is poorly understood, because basic data is lacking on USLE factor values for rangeland conditions. Problems associated with applying the USLE to the Reynolds Creek Watershed are:

1. The rainfall and runoff factor, R, does not properly account for snowmelt and frozen soil runoff.

2. Soil erodibility, K, values for rock pavements and rocky soils are questionable.

3. Slope-length factor, L, values on sagebrush rangelands are probably much less than on cultivated lands, because rills are usually short and discontinuous on rangeland slopes.

4. Cover and management factor, C, values for rangelands with well distributed dense-rooted grasses and shrubs are commonly overestimated. Rangeland vegetation is probably more effective in controlling soil loss than evenly spaced cultivated crops with a similar percent ground and canopy cover.

Presently, the greatest need in applying the USLE to rangelands is developing a procedure similar to that of Dissmeyer and Foster, 1980, for forest lands. To accomplish this, standard rainfall simulation erosion measurements and natural runoff plots are needed to provide basic data, similar to extensive data used in development of the USLE for cultivated areas. Meanwhile, the USLE is useful in predicting relative effects of grazing and brush control on potential erosion (Johnson, et al., 1980; Northwest Watershed Research Center, 1980).

SEDIMENT YIELD STUDIES

Pacific Southwest Inter-agency Committee (PSIAC) procedure:
The PSIAC procedure (Pacific Southwest Inter-agency Committee, 1968) was adapted for using Reynolds Creek Watershed data (Northwest Watershed Research Center, 1979). Predicted sediment yields were within about 15 percent of measured watershed sediment yields. The PSIAC ground cover, land use, and upland erosion factors increased with grazing and predicted sediment yields were about 14 percent

greater on grazed than on ungrazed areas. Sagebrush eradication by spraying increased predicted sediment yields about 8 percent, and brush eradication by cutting and removal increased predicted yields about 12 percent on ungrazed areas (Johnson and Gebhardt, 1982).

Results of this study show the PSIAC procedure can be used to predict long-term watershed sediment yields from sagebrush rangelands where data are available to evaluate the factors. Also, the PSIAC factors influenced by changes in land use appear to respond properly for the cases tested.

Modified Universal Soil Loss Equation (MUSLE):

The MUSLE was developed by Williams, 1975, to eliminate the sediment delivery ratio when applying the USLE to watersheds and specific storm runoff and sediment data. Williams replaced the conventional rainfall-runoff factor, R, in the USLE with a runoff energy factor to produce the MUSLE,

$$S = 95(Q \times q_p)^{0.56} \times K \times LS \times C \times P$$

where S is sediment yield in tons, Q is runoff volume in acre-feet, q_p is peak flow rate in ft^3/sec, and K LS C P are as defined in the USLE. The coefficient, 95, and exponent, 0.56, were determined by optimization, Williams, 1975.

Runoff and suspended sediment yield data from four Reynolds Creek Experimental Watershed stations at Outlet, Macks Creek, Tollgate, and Reynolds Mountain, Figure 1, were analyzed using the MUSLE, Table 4.5. First, data from individual events (runoff hydrographs and sediment transport records) were separated into rainfall, snowmelt, and mixed, rainfall and snowmelt categories. Next, data for the

Table 4.5.--Watersheds used in MUSLE analysis.

Watershed	Drainage area	Mean elevation	Average slope	Number of events
	-acres-	---ft---	---%---	
Reynolds Outlet	57,754	4900	17	242
Macks Creek	7,846	4930	18	160
Reynolds Tollgate	13,453	6100	26	330
Reynolds Mountain	100	6830	14	371

following runoff and sediment yield components of each event were determined:

1. Total peak streamflow rate in ft^3/sec.

2. Total runoff volume in acre-feet.

3. Total sediment yield in tons.

4. Storm peak streamflow rate in ft^3/sec (total peak flow rate less the base flow rate).

5. Storm runoff volume in acre-feet (total volume less the baseflow volume).

6. Storm sediment yield in tons (total sediment yield less the sediment yield associated with base flow).

Minimum, maximum, and mean values in each category are summarized in Table 4.6. Generally, events included a wide range of values with mixed rain and snowmelt contributing greatest peak flows, volumes, and sediment yields. The optimized best fit equations for each watershed and category are listed in Table 4.7, assuming constant KLSCP values. Overall, storm runoff components showed a slightly better fit than total runoff components. Equations from rainfall events were most similar to the Williams' equation. Multiple correlation coefficients, r, ranged widely with Macks Creek data showing best results.

Average yearly suspended sediment yields are shown in Table 4.8, to evaluate the relative importance of rainfall, snowmelt, and mixed rain and snowmelt in transporting sediment from each watershed. The Reynolds Outlet and Macks Creek watersheds, mean elevation about 4900 feet, show nearly 90 percent sediment yield from mixed events. Reynolds Creek at Tollgate, mean elevation 6100 feet, shows 63 percent sediment yield from mixed events, and 36 percent from snowmelt. Reynolds Mountain, mean elevation 6800 feet, shows 66 percent sediment yield from snowmelt.

Rangeland Soil Loss and Sediment Yield Predictions:

The USLE has not been thoroughly validated on rangelands. Consequently, it should be used mainly to show relative effects of fires, grazing, seeding, land disturbance, and other land use changes on small areas where sediment deposition is not significant. Major questions on effects of snowmelt and frozen soil runoff, rocky soils, slope length, extremely steep slopes, and rangeland vegetation are yet to be answered in accurately predicting soil losses. Generally, conventional application of the USLE appears to overpredict rangeland soil losses, compared with measured sediment yields.

Results of predicting sediment yields using the PSIAC procedure show reasonable agreement with measured yields from sagebrush rangeland watersheds. The procedure is relatively simple, can be applied to

Table 4.6.--Summary of peak flow rates, runoff volumes, and sediment yields for the period of record, Reynolds Creek Experimental Watershed.

Watershed and period of record	Category and no. of events	Range of values	Peak streamflow Total	Peak streamflow Storm	Runoff volume Total	Runoff volume Storm	Sediment yield Total	Sediment yield Storm
			---ft^3/sec----		--acre-feet--		-----tons-----	
Reynolds Outlet (1967-80)	Rainfall (11)	Min.	51	28	8	5	20	19
		Max.	821	815	200	57	1881	1879
		Mean	187	146	117	33	321	302
	Snowmelt (91)	Min.	39	11	47	8	12	4
		Max.	225	126	449	112	1127	852
		Mean	117	48	178	39	139	92
	Mixed (140)	Min.	17	2	12	1	1	0.1
		Max.	1663	1653	2689	2032	34713	33766
		Mean	198	127	284	108	1116	968
Macks Creek (1968-80)	Rainfall (13)	Min.	3.9	3.6	2	1.4	1	0.9
		Max.	86	79	129	51	268	268
		Mean	32	28	28	15	66	64
	Snowmelt (58)	Min.	3	2	3	1	0.2	0.1
		Max.	71	50	123	75	313	303
		Mean	21	13	25	9	22	19
	Mixed (89)	Min.	3	1	4	1	0.2	0.1
		Max.	327	304	486	357	5501	5301
		Mean	53	41	64	32	288	274
Reynolds Tollgate (1967-80)	Rainfall (5)	Min.	15	11	17	8	5	5
		Max.	102	93	46	30	46	44
		Mean	43	39	30	18	22	20
	Snowmelt (190)	Min.	16	5	24	4	4	1
		Max.	218	100	337	82	766	684
		Mean	89	28	144	24	98	69
	Mixed (135)	Min.	9	2	11	1	1	0.5
		Max.	403	345	1012	616	7330	7225
		Mean	100	52	170	55	256	230
Reynolds Mountain (1969-80)	Rainfall (2)	Min.	0.2	0.2	0.2	0.1	.01	.01
		Max.	1.5	0.9	1.2	0.3	.06	.05
		Mean	0.9	0.6	0.7	0.2	.03	.03
	Snowmelt (259)	Min.	0.1	0.02	0.1	0.02	.002	.001
		Max.	5.9	4.4	7.7	3.0	2.4	2.2
		Mean	2.2	0.9	3.2	0.7	0.24	0.18
	Mixed (110)	Min.	0.2	0.1	0.4	0.1	0.01	.001
		Max.	9.3	6.2	9.3	4.5	2.6	2.4
		Mean	2.1	1.1	3.2	0.83	0.29	0.22

Table 4.7.--MUSLE optimization fitted coefficients and exponents, Reynolds Creek Experimental Watersheds.

Watershed	Category	Equation	KLSCP	r
Reynolds Outlet	Rainfall total	$s = 0.01\ (Qxq_p)^{1.43}$	0.0166	0.79
	Snowmelt total	$s = 0.02\ (Qxq_p)^{1.26}$	0.0166	0.59
	Mixed total	$s = 1.02\ (Qxq_p)^{0.97}$	0.0166	0.85
	Rainfall storm	$s = 2.28\ (Qxq_p)^{1.02}$	0.0166	0.99
	Snowmelt storm	$s = 1.02\ (Qxq_p)^{1.12}$	0.0166	0.67
	Mixed storm	$s = 266\ (Qxq_p)^{0.58}$	0.0166	0.80
Macks Creek	Rainfall total	$s = 234\ (Qxq_p)^{0.42}$	0.0183	0.71
	Snowmelt total	$s = 0.22\ (Qxq_p)^{1.30}$	0.0183	0.98
	Mixed total	$s = 4.05\ (Qxq_p)^{0.94}$	0.0183	0.97
	Rainfall storm	$s = 178\ (Qxq_p)^{0.51}$	0.0183	0.82
	Snowmelt storm	$s = 1.92\ (Qxq_p)^{1.15}$	0.0183	0.96
	Mixed storm	$s = 26.5\ (Qxq_p)^{0.80}$	0.0183	0.97
Reynolds Tollgate	Rainfall total	$s = 39.1\ (Qxq_p)^{0.50}$	0.0171	0.84
	Snowmelt total	$s = 0.05\ (Qxq_p)^{1.20}$	0.0171	0.73
	Mixed total	$s = 0.02\ (Qxq_p)^{1.50}$	0.0171	0.94
	Rainfall storm	$s = 54.1\ (Qxq_p)^{0.48}$	0.0171	0.79
	Snowmelt storm	$s = 7.64\ (Qxq_p)^{0.94}$	0.0171	0.78
	Mixed storm	$s = 0.10\ (Qxq_p)^{1.26}$	0.0171	0.91
Reynolds Mountain	Snowmelt total	$s = 1.67\ (Qxq_p)^{0.88}$	0.0221	0.63
	Mixed total	$s = 3.48\ (Qxq_p)^{0.67}$	0.0221	0.60
	Snowmelt storm	$s = 7.42\ (Qxq_p)^{0.91}$	0.0221	0.80
	Mixed storm	$s = 11.45(Qxq_p)^{0.53}$	0.0221	0.58

Table 4.8.--Average yearly total suspended sediment yields by runoff category, Reynolds Creek Watersheds.

Watershed	Sediment yield, tons (percent of total)			
	Rainfall	Snowmelt	Mixed rain-snow	Total
Reynolds Outlet	589(4)	1,149(8)	12,014(88)	13,752
Macks Creek	143(6)	128(5)	2,331(89)	2,602
Reynolds Tollgate	37(1)	1,545(36)	2,662(63)	4,244
Reynolds Mountain	0.03(0)	5.26(66)	2.67(34)	7.96

large areas, and has factors to account for range treatments and management changes. It is most useful in predicting long-term annual yields and in identifying problem areas.

The MUSLE has great potential for use in rangeland modeling, where data are available to accurately evaluate individual factors and interactions among processes associated with sediment movement are understood. Applications of the equation on an event basis encourage its increased use in modeling large watershed areas.

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5. WATER QUALITY

Personnel Involved

G. R. Stephenson, Geologist	Responsible for coordinating activities with cooperators. Designs collection network and responsible for project completion.
R. C. Rychert, Microbiologist (Summer Employment)	Cooperator in microbiological aspects of rangeland streams as affected by grazing practices.
A. P. Veigel, Scientific Aid (U. of Idaho Cooperator)	Responsible for collection of water samples and laboratory analyses; assists in data processing.

WATER QUALITY OBSERVATIONS - BOISE FRONT

Water quality baseline information continues to be developed from samples collected at four sites on the Boise Front rest-rotation grazing system. The four sites are located immediately upstream from weirs, which record runoff. The sites are located such that the data will reflect the grazing practices. Figure 5.1 gives the site location and the scheduled grazing activity for 1981.

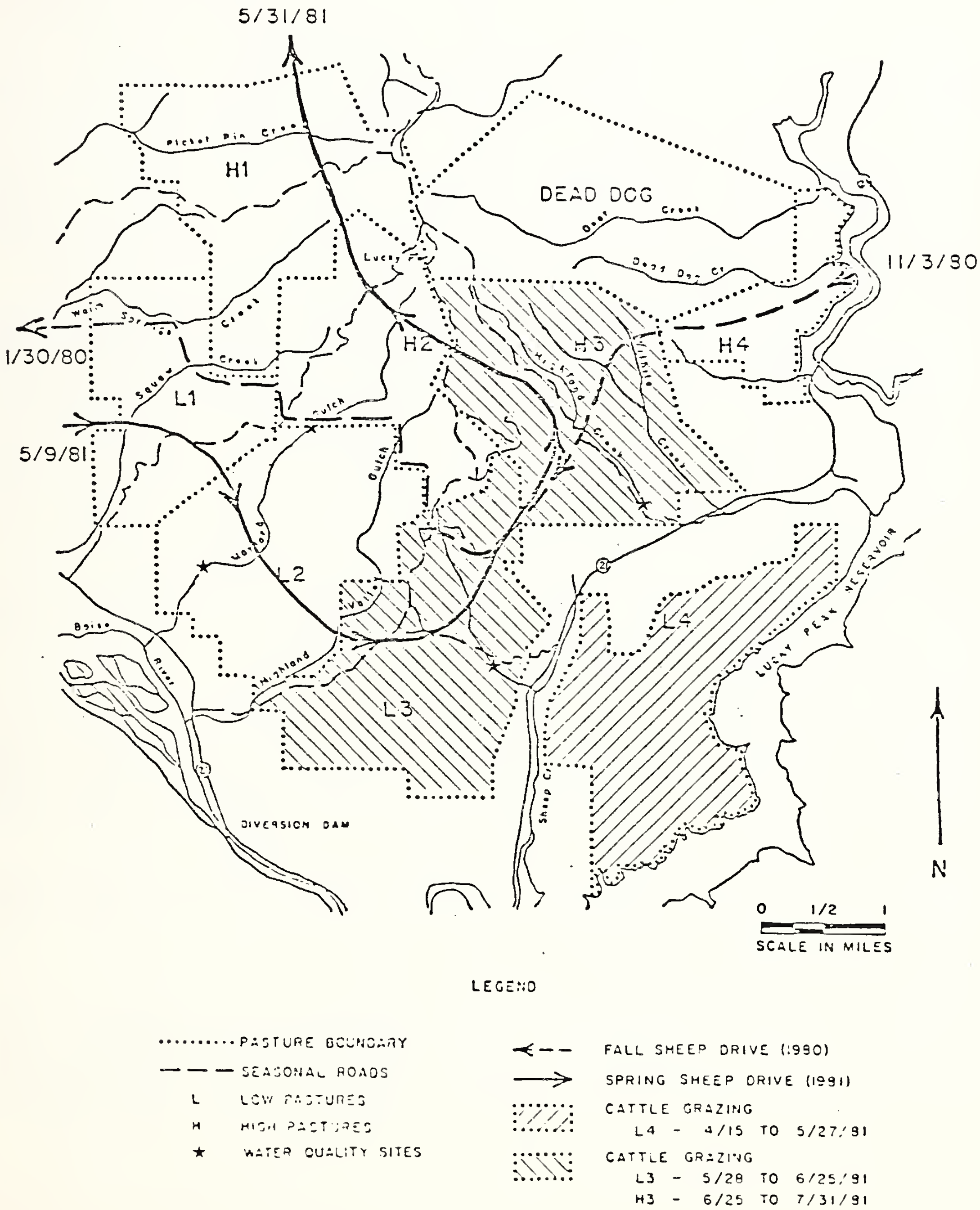

Figure 5.1.--Boise Front site locations and grazing activity, 1981.

Table 5.1 gives the water quality data for the four sites for 1979-1981 water years (Oct. 1 - Sept. 30). Total number of samples varies because of intermittent streamflow at several sites.

Table 5.1.--Water quality characteristics, Boise Front Watershed sampling sites, 1979-81.

Parameters	Units	No. of Samples (1981)	Maximum 1979	Maximum 1980	Maximum 1981	Minimum 1979	Minimum 1980	Minimum 1981	Average 1979	Average 1980	Average 1981
					Lower Maynard						
pH	units	18	8.35	7.95	8.00	6.67	7.20	7.10	7.73	7.61	7.54
Conductivity	umhos	15	216.00	207.62	252.88	111.23	89.59	133.95	171.51	136.49	176.56
Dissolved solids	mg/l	15	149.97	143.93	174.48	54.53	62.46	92.43	114.05	95.03	121.83
Calcium	mg/l	18	19.34	17.90	20.80	10.52	7.63	9.90	14.52	12.68	15.58
Magnesium	mg/l	18	2.95	2.70	3.90	2.00	1.66	2.15	2.35	2.14	3.03
Sodium	mg/l	17	15.49	10.80	9.80	3.00	7.30	6.70	7.90	8.95	8.64
Phosphorous	mg/l	13	0.03	0.27	0.16	0.03	0.03	0.05	0.03	0.09	0.08
Nitrate	mg/l	6	0.03	1.16	0.40	0.03	0.64	0.28	0.03	0.84	0.35
SiO_2	mg/l	--	36.00	40.00	--	21.50	27.00	--	32.78	33.50	--
Sodium absorption ratio	ratio	--	--	--	--	--	--	--	--	--	--
Suspended solids	mg/l	5	167.60	124.00	20.00	3.00	3.00	0.00	21.28	33.89	8.60
Total coliform	cts/100 ml	16	980.00	38400.00	120000.00	0.00	300.00	600.00	234.00	8139.31	22891.25
Fecal coliform	cts/100 ml	17	675.00	580.00	3350.00	0.00	0.00	5.00	81.52	49.07	252.35
Fecal strep	cts/100 ml	18	3320.00	3700.00	1360.00	0.00	8.00	4.00	431.81	473.86	298.72
COD	mg/l	--	6.14	27.78	--	0.00	0.00	--	2.89	6.84	--
BOD	mg/l	1	3.40	1.90	5.50	0.00	0.00	5.50	1.05	1.75	5.50
DO	mg/l	17	10.00	10.50	10.00	5.50	7.50	5.00	8.35	9.13	7.94
					Camp Creek						
pH	units	9	8.20	8.00	7.80	6.92	7.40	7.20	7.68	7.72	7.58
Conductivity	umhos	6	166.80	200.21	334.60	142.80	129.20	167.00	153.78	161.24	210.56
Dissolved solids	mg/l	6	115.92	139.10	230.87	99.36	89.73	115.23	107.02	111.54	145.29
Calcium	mg/l	9	11.23	18.00	27.40	11.23	10.80	12.80	11.23	15.13	17.69
Magnesium	mg/l	9	2.64	3.40	8.90	2.64	2.42	1.60	2.64	2.86	4.29
Sodium	mg/l	9	9.76	10.90	11.30	9.76	7.90	7.40	9.76	8.94	9.33
Phosphorous	mg/l	7	0.03	0.23	0.18	0.03	0.04	0.08	0.03	0.10	0.12
Nitrate	mg/l	1	0.03	--	0.14	0.03	--	0.41	0.03	--	0.41
SiO_2	mg/l	--	32.00	45.00	--	32.00	27.00	--	32.00	36.00	--
Sodium absorption ratio	ratio	3	--	--	9.20	--	--	3.00	--	--	6.07
Suspended solids	mg/l	--	19.00	161.50	--	3.00	3.00	--	11.50	53.46	--
Total coliform	cts/100 ml	8	775.00	22000.00	170000.00	12.00	20.00	2500.00	139.67	4946.80	63625.00
Fecal coliform	cts/100 ml	7	528.00	270.00	13000.00	0.00	0.00	4.00	110.33	45.72	4062.28
Fecal strep	cts/100 ml	9	550.00	2000.00	1800.00	4.00	6.00	8.00	124.33	248.08	751.11
COD	mg/l	--	--	26.11	--	--	0.00	--	--	8.78	--
BOD	mg/l	--	--	1.50	--	--	0.50	--	--	1.00	--
DO	mg/l	8	10.00	10.50	10.00	9.50	7.00	5.50	9.67	8.54	7.19
					Upper Maynard						
pH	units	26	8.20	8.20	8.00	6.53	7.30	7.10	7.70	7.70	7.61
Conductivity	umhos	26	227.05	199.26	280.00	96.00	78.40	129.20	159.32	153.33	139.25
Dissolved solids	mg/l	26	158.63	167.81	193.20	66.65	54.43	89.15	110.77	103.25	123.69
Calcium	mg/l	27	18.61	27.90	28.50	9.10	6.47	5.54	12.57	14.61	16.73
Magnesium	mg/l	27	2.87	3.68	5.85	1.65	1.32	1.56	1.92	2.67	3.06
Sodium	mg/l	24	8.00	12.80	12.10	2.90	6.25	6.60	[illegible]	[illegible]	8.99
Phosphorous	mg/l	24	0.03	0.22	0.19	0.03	0.03	0.04	0.02	0.09	0.09
Nitrate	mg/l	6	0.02	1.41	1.23	0.02	0.66	0.25	0.02	1.03	0.56
SiO_2	mg/l	--	39.55	37.00	--	20.00	26.75	--	29.78	30.42	--
Sodium absorption ratio	ratio	--	--	--	--	--	--	--	--	--	--
Suspended solids	mg/l	5	23.50	120.40	9.00	2.00	3.00	2.80	7.63	30.58	5.56
Total coliform	cts/100 ml	22	2300.00	40000.00	268000.00	0.00	100.00	1500.00	382.13	9833.43	36950.00
Fecal coliform	cts/100 ml	26	1322.00	3820.00	20600.00	0.00	0.00	9.00	230.13	310.27	1262.00
Fecal strep	cts/100 ml	26	3220.00	9300.00	7600.00	13.00	18.00	5.00	368.52	919.78	853.50
COD	mg/l	5	13.10	25.19	8.80	0.00	0.00	1.70	4.80	7.38	4.96
BOD	mg/l	1	2.50	2.50	4.80	0.00	0.00	4.80	0.55	0.96	4.80
DO	mg/l	28	10.00	10.50	12.00	7.00	5.00	5.00	8.24	8.50	8.13
					Highland Valley						
pH	units	42	8.10	9.20	8.00	6.50	7.15	7.00	7.52	7.62	7.45
Conductivity	umhos	41	275.63	232.00	310.00	118.30	118.80	111.78	171.53	149.90	173.06
Dissolved solids	mg/l	41	192.51	161.46	213.90	82.11	75.62	77.13	119.38	107.30	119.41
Calcium	mg/l	43	22.37	16.50	19.10	10.79	8.20	5.39	17.43	13.30	12.55
Magnesium	mg/l	43	3.15	3.58	7.05	2.30	1.86	2.62	2.83	2.92	4.50
Sodium	mg/l	42	14.28	8.80	15.70	2.80	6.10	6.60	9.52	7.60	8.51
Phosphorous	mg/l	35	0.16	0.30	0.21	0.05	0.07	0.06	0.10	0.14	0.13
Nitrate	mg/l	14	0.24	6.33	9.16	0.24	2.82	1.71	0.24	4.37	4.08
SiO_2	mg/l	--	42.21	42.00	--	26.50	27.50	--	34.61	34.42	--
Sodium absorption ratio	ratio	--	--	--	--	--	--	--	--	--	--
Suspended solids	mg/l	15	210.70	621.80	178.00	2.00	14.50	4.00	23.76	111.92	31.87
Total coliform	cts/100 ml	39	31000.00	32000.00	490000.00	0.00	100.00	1000.00	3646.75	8308.72	39132.82
Fecal coliform	cts/100 ml	40	23200.00	3500.00	6280.00	0.00	14.00	0.00	1295.06	240.66	704.75
Fecal strep	cts/100 ml	41	99000.00	9300.00	11800.00	0.00	12.00	15.00	5655.69	1020.47	1338.78
COD	mg/l	6	39.57	92.70	12.70	2.00	0.58	2.40	9.61	14.42	7.10
BOD	mg/l	9	6.40	5.00	9.20	0.00	0.00	4.70	1.65	1.67	7.49
DO	mg/l	43	9.50	10.50	10.50	6.00	6.00	5.50	7.76	8.66	7.85

When comparing the data from Table 5.1 for 1979-1981, the most significant indicator of water quality variations continues to be the fecal coliform concentration. The fecal coliform indicator relates directly to the presence of warm blooded animals and reflects, mainly, the effects of the rest-rotation grazing management system. Other indicators, such as suspended solids and nutrients, show some variation between sites and between sampling dates, but are more frequently the result of runoff characteristics than the absence or presence of livestock.

Table 5.2 gives the average fecal coliform concentration for the four sites for the past three years. Each site reflects the water quality of the runoff from the individual grazing pastures within the rest-rotation system. During the years cattle graze the individual pastures, the average fecal coliform concentration is usually the highest. In 1980, pasture L2, the Lower Maynard site, was grazed, but the stream was dry when the cattle were turned in, so no samples were taken. The cattle obtained water from spring flow developments. In 1981, pasture H2, Upper Maynard, was not scheduled for grazing, but had a very high fecal coliform average. The reason for this was that, because of low stream flow, gates between pastures were left open so cattle could move between pastures H3 and H2. Consequently, pasture H2 was grazed in 1981 even though the grazing schedule called for the pasture to be rested.

Table 5.2.--Average fecal coliform concentrations.

		1978	1979	1980	1981
Lower Maynard	(L2)	$\boxed{225}$ *	82	$\boxed{49}$ **	252
Camp Creek	(L3)	38	$\boxed{110}$	45	$\boxed{4062}$
Upper Maynard	(H2)	$\boxed{217}$	230	$\boxed{310}$	1262
Highland Valley	(H3)	193	$\boxed{1295}$	240	$\boxed{704}$

*Framed values indicate field grazed that year.

**Cattle not turned in until after October 1, 1980. Streams were dry; no samples.

Figure 5.2 shows graphically the variations in fecal coliform concentration throughout the water year at all four sites on the Boise Front. Evidence of the large deer herd wintering in this area is recorded in periodic increases in fecal coliform concentration at all sites through the winter and spring months. The Highland Valley site (H3) shows the largest influence of deer, especially in April and May, as the herd moves through that area to higher country for the summer.

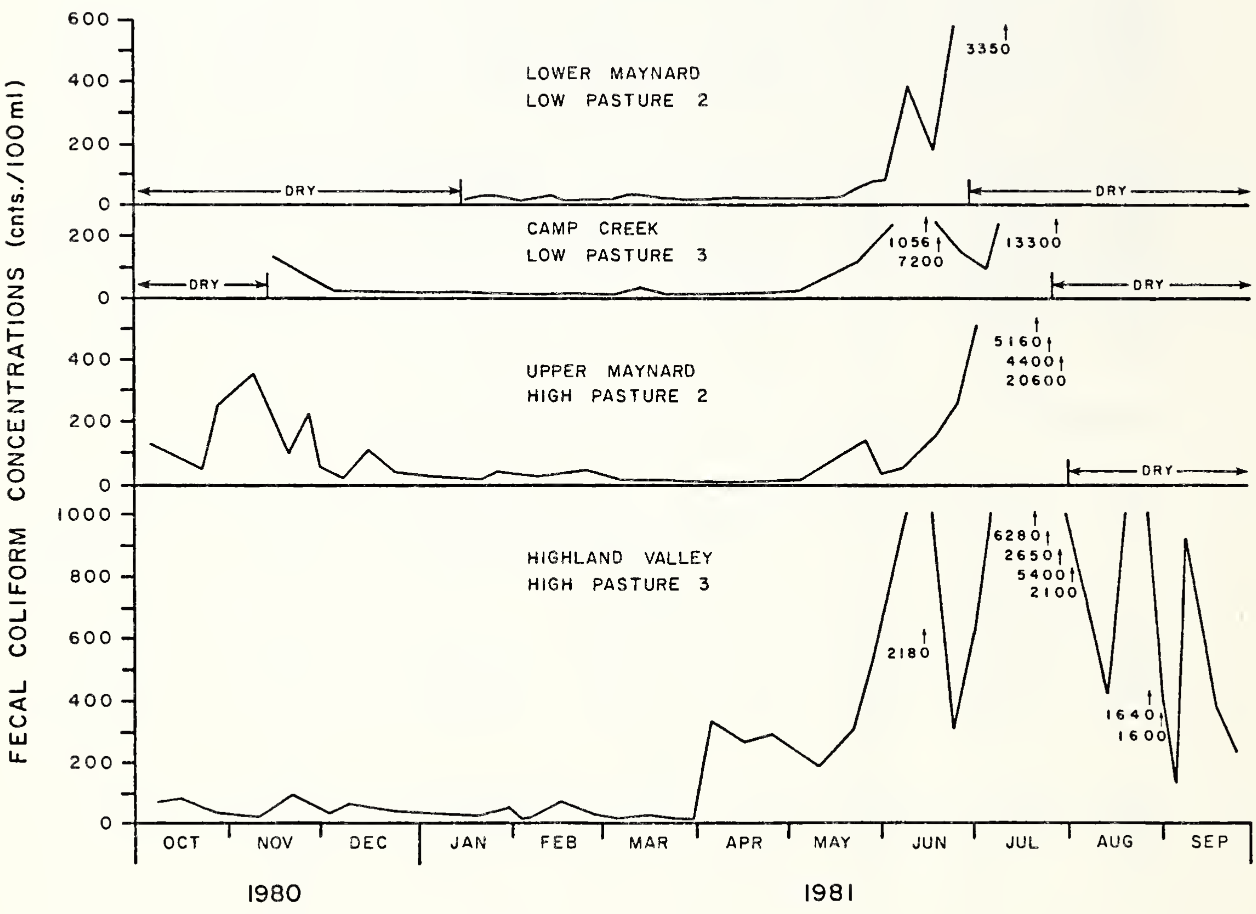

Figure 5.2.--Fecal coliform concentration, Boise Front sampling sites.

The 1980 fall sheep drive passed through pastures H3, L3, and H2 in November. Evidence of their passage, recorded in elevated fecal coliform concentration at the stream site, is recorded only at the Highland Valley and Upper Maynard sites. The Camp Creek site, located in pasture L3, was dry. The 1981 spring sheep drive occurred during May, and passed through L2, L3, H3, and H2, respectively. Elevated fecal coliform counts are recorded at all sampling sites in these pastures at this time. Cattle entered low pasture 3 in late May. The effect of their presence was recorded immediately in elevated fecal coliform counts at the Camp Creek site as they frequented the riparian habitat for water, shade, and more palatable grass. The cattle moved out of pasture L3 into pasture H3 in late June, but fecal coliform concentration remained high until the stream above the Camp Creek site dried up in early July.

Even though cattle were scheduled to be in pasture H3 by early July, the streams were running low and gates into L3, L2, and H2 were opened so the cattle could utilize these pastures. As the weather became hotter and drier, all the streams dried up, except above the Highland Valley site, high pasture 3. As seen in Figure 5.2, the elevated fecal coliform concentration at this site remained high until late summer as the cattle moved into this area for better grass, water, and cooler air temperatures.

Model evaluation and parameter testing:

Water quality model guidelines were evaluated this year. Since bacterial parameters appear to be the most sensitive indicator of nonpoint source pollution in rangeland streams, attempts are being made to develop a user oriented microbiology predictive method to simulate bacterial variations in these environments. During this first attempt, the following independent variables were selected along with fecal coliform concentration as the dependent variable: runoff, dissolved oxygen, water temperature, average slope, aspect, drainage density, vegetative characteristics, channel roughness, and grazing practice (number of cattle). Relationships between land form factors, such as slope steepness and drainage density, and bacterial factors were found to exist in most grazing allotments. The greater the drainage density (stream length per unit area), the lower the overall bacterial concentration; and the steeper the slopes, the higher the overall bacterial concentration. Both factors influence the distribution of livestock and their proximity to streams.

Regression techniques were used to test for parameter relationships. The initial test, using dissolved oxygen, temperature, and streamflow as independent variables, and fecal coliform concentration as the dependent variable proved unsuccessful, as correlations were not significant. However, individual parameter correlations with fecal coliforms, using linear regressions, were significant. Suspended sediment, $r^2 = .79$, was correlated with fecal coliforms, as was channel roughness, $r^2 = .96$. The latter parameter had a negative slope. Testing of these parameters will continue for model development.

E. coli occurrence and survival:
Several detailed studies were completed this year to determine the survival of E. coli in different environments. In order to test previous findings, which demonstrated that stream sediments can serve as a reservoir of E. coli, a detailed sampling network was carried out during January through October. The mean E. coli concentrations for the sediment to water ratio was 13.5, confirming previous findings. E. coli survival in the stream sediments is often carried over from one grazing season to another, and frequently experiences regrowth. E. coli in the overlying stream water, however, seldom remain viable in the water for any length of time. The stream environment varies considerably with roughness, temperature, and predators, etc.; whereas, the sediment environment is quite stable. Disturbance of the sediment causes resuspension of the bacterial indicators in the overlying waters.

In order to determine seasonal die-off, regrowth, and movement of E. coli (fecal coliforms) in fresh fecal material in rangeland environments, eight paired sites were selected with varying slopes, aspects, vegetation, and soil characteristics. Weekly samples were taken from cow pies freshly deposited in May and in October. Results show that E. coli populations die off rapidly during the summer months, because of dessication of the fecal material. Less than 0.1 percent of the original population remained after two months. Weekly samples from fresh October deposits, subject to freezing and thawing, show a die-off rate of one order of magnitude less, with a low level of regrowth occuring on south facing slopes during the following spring. This is followed by complete summer die-off. Movement of E. coli from the cow pies into the soil following rain storms was negligible, even on the steeper slopes. Slope, aspect, soil type, and vegetative composition show no consistent relationships with die-off or regrowth. Final conclusions of these experiments are: (1) fecal material from livestock, as sources of fecal bacteria in rangeland streams, must either be deposited in the stream or transported to the streams by animals or immediately adjacent runoff; and (2) E. coli (fecal coliforms) die off rapidly during hot dry weather, but may remain viable during cool, moist weather, and can experience regrowth the following spring.

In the continuing investigation of the cause of atypical E. coli in rangeland streams, the effects of antibiotics in cattle feed were investigated. Preliminary results indicate that 13 percent of the atypical E. coli isolates were resistant to two or more antibiotics,; whereas, 72 percent of the typical E. coli were resistant. This indicates that a higher percentage of the fecal coliforms in these rangeland streams are multiply-resistant to antibiotics, and could represent a significant health hazard not previously recognized.

PUBLICATIONS, REPORTS, AND PAPERS

PRECIPITATION

VEGETATION AND SOILS

RUNOFF AND WATER YIELD

EROSION AND SEDIMENT

WATER QUALITY

PRECIPITATION

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